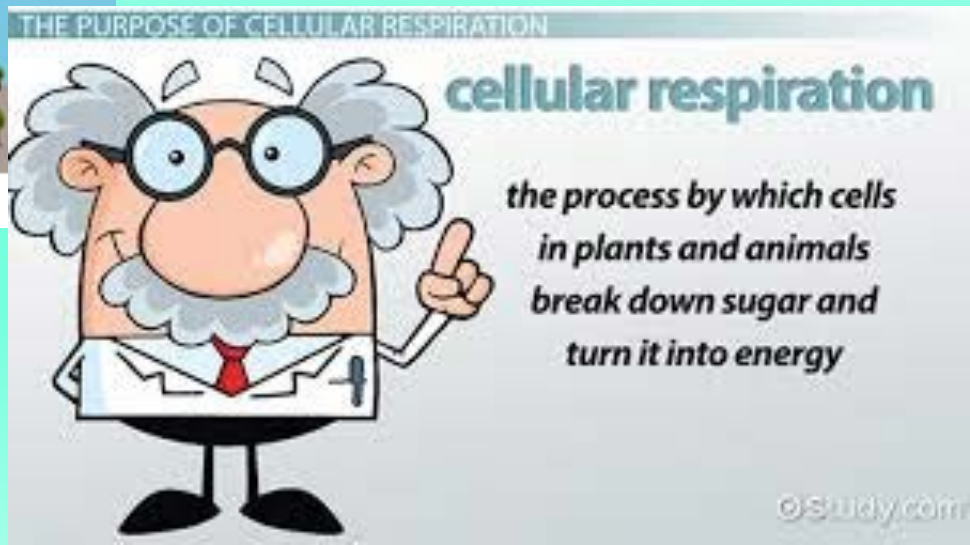
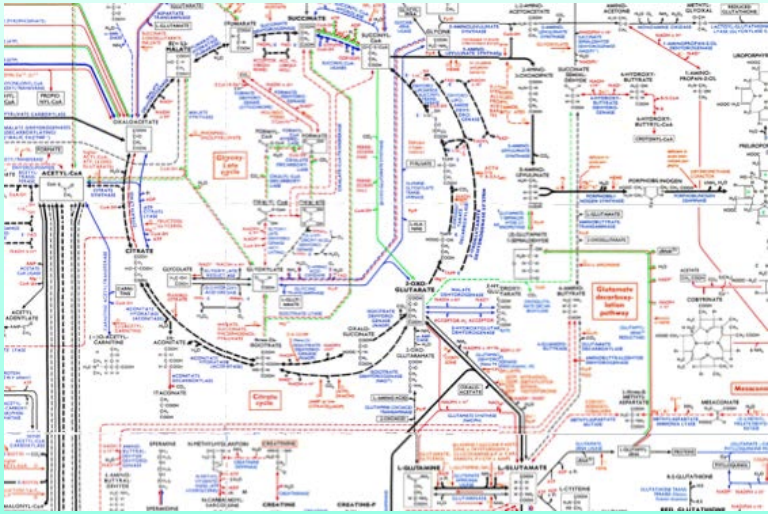
Cellular Respiration


THE PURPOSE OF CELLULAR RESPIRATION
cellular respiration
the process by which cells in plants and animals break down sugar and turn it into energy
©Study.com

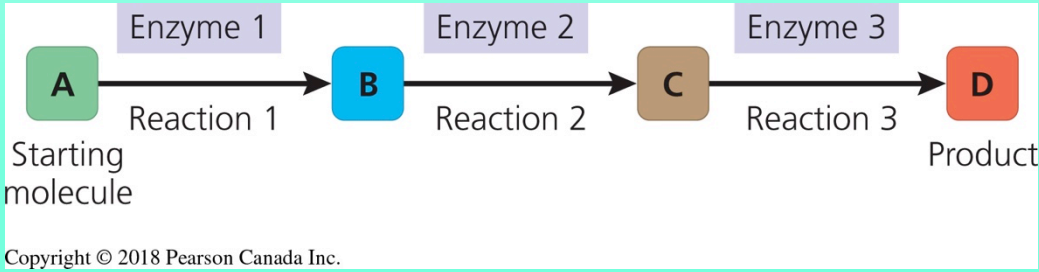
Metabolism

All chemical reactions taking place in an organism.



Metabolic Pathway

A particular sequence of connected reactions.



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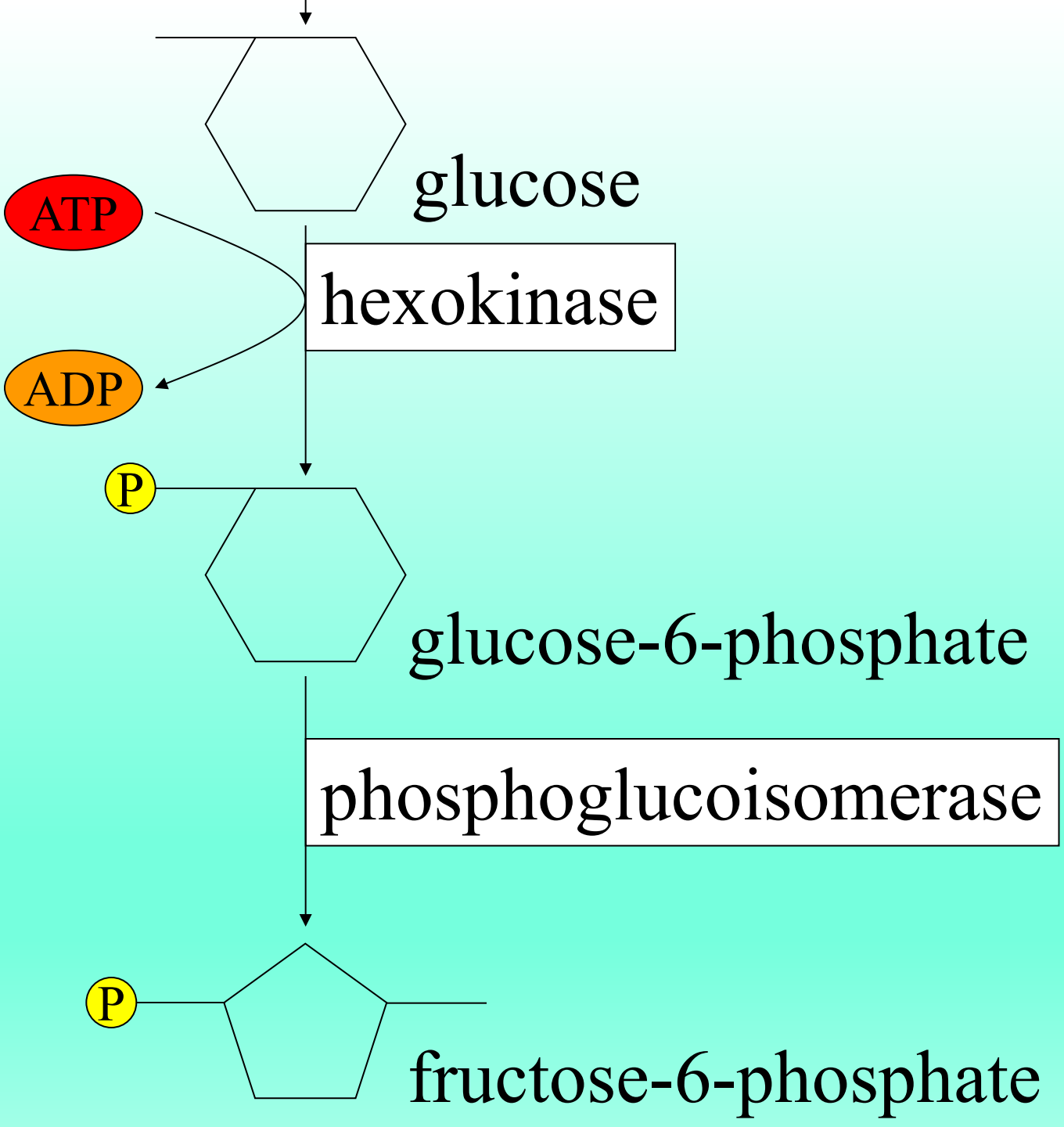
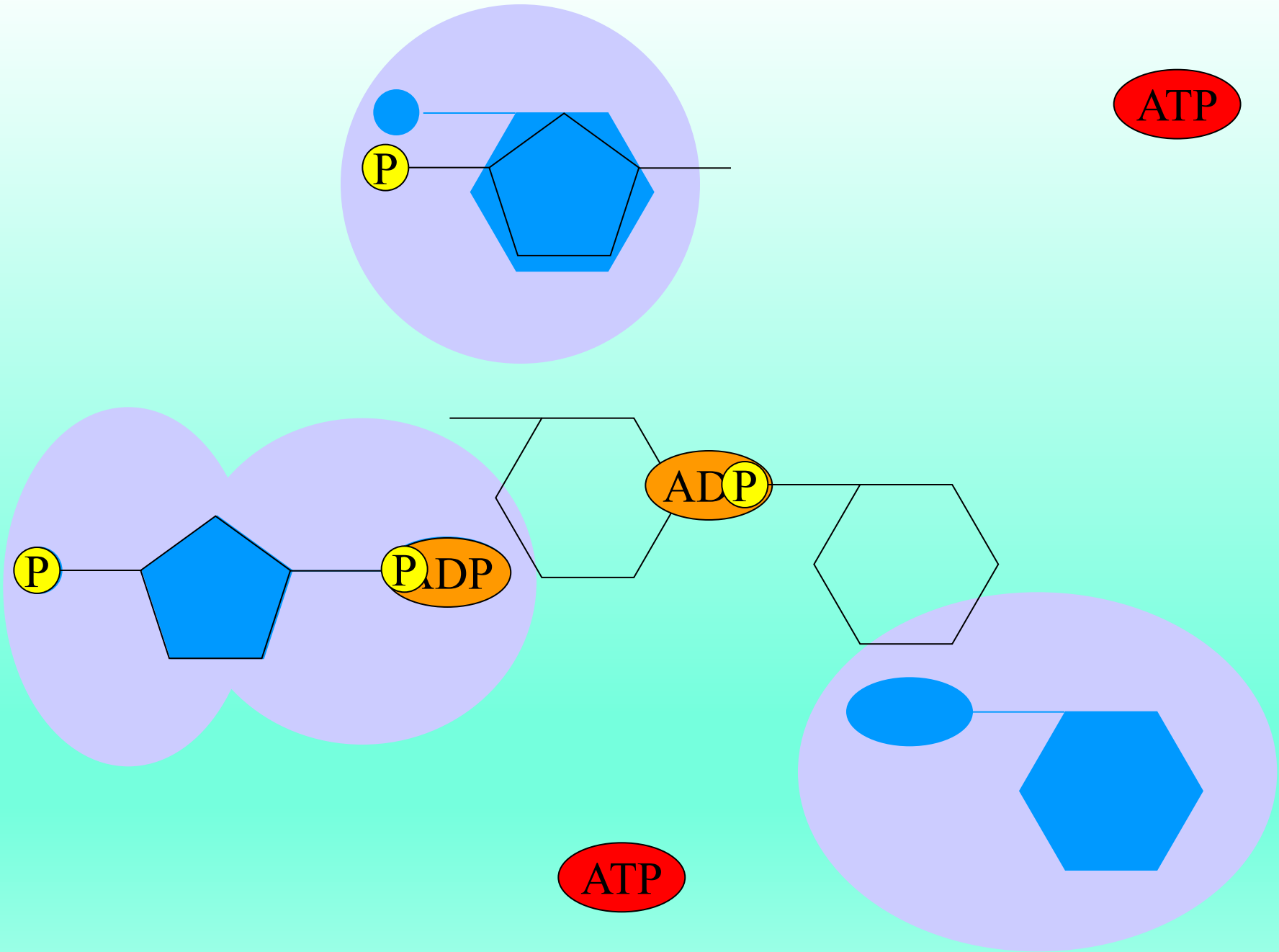
Enzyme

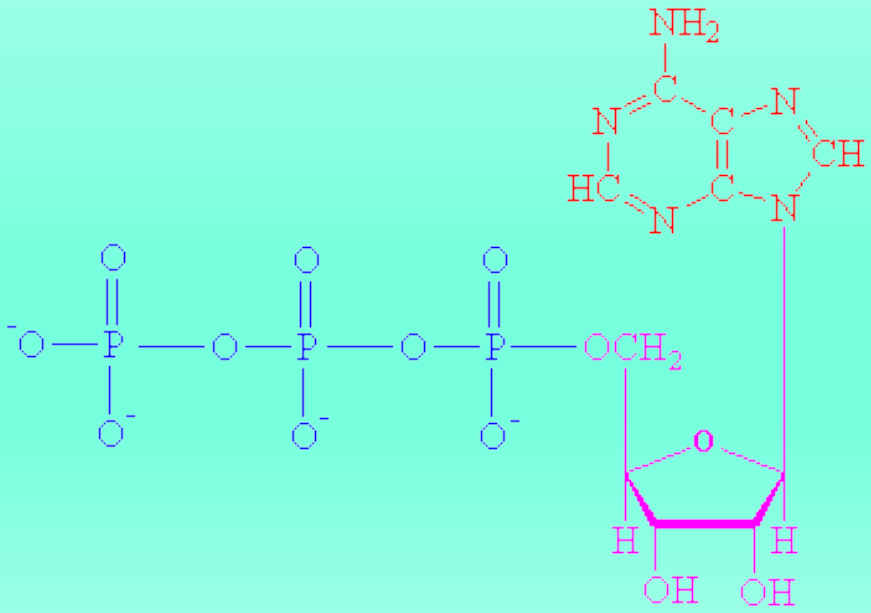
A protein that facilitates a specific chemical reaction.


glucose
ATP
hexokinase
ADP
P
glucose-6-phosphate
phosphoglucoisomerase
P
fructose-6-phosphate


ATP
P
P
P
ADP
ADP
ATP

ATP (Adenosine TriPhosphate)

A high-energy molecule used to provide energy in cells.

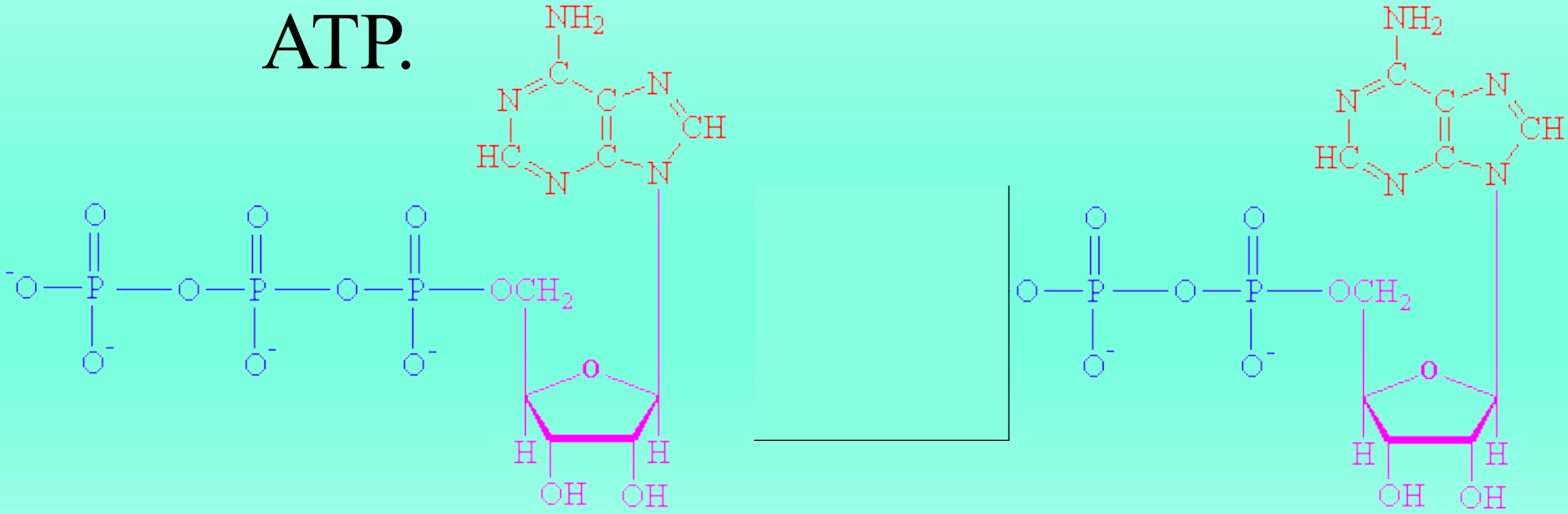


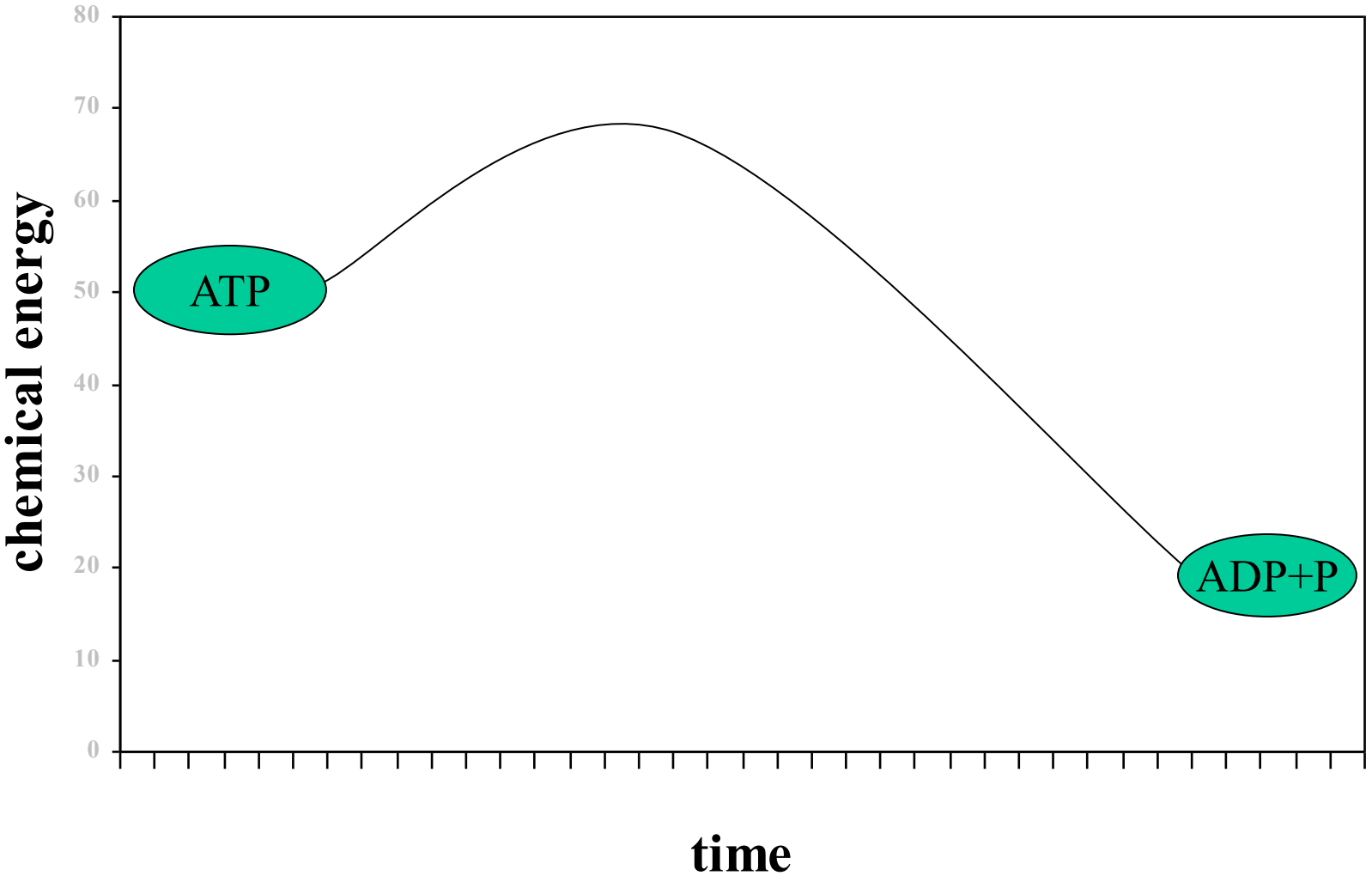
ATP (Adenosine TriPhosphate)

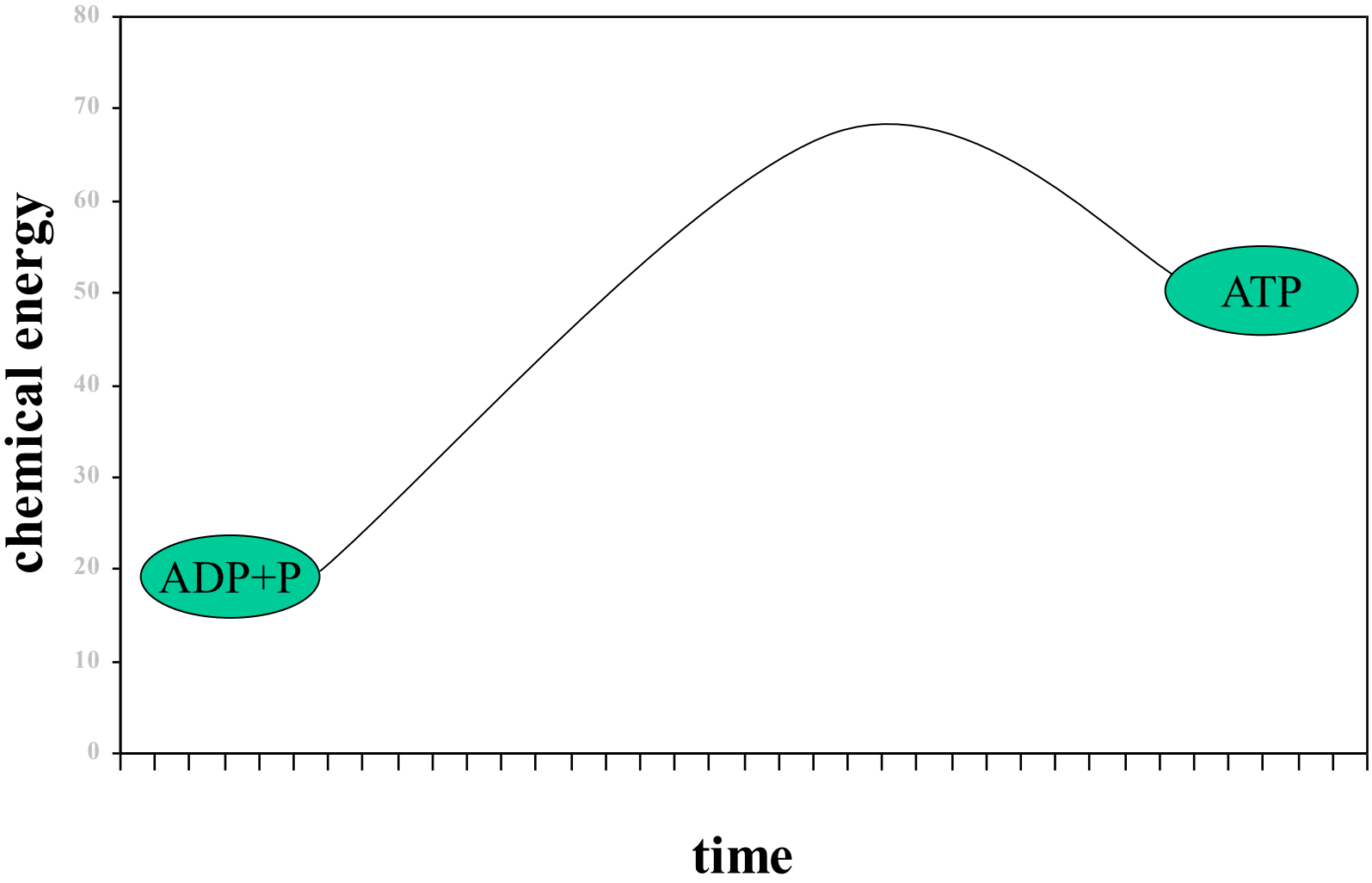
A high-energy molecule used to provide energy in cells.

ADP (Adenosine DiPhosphate)

The lower-energy form of ATP.




chemical energy
80
70
60
50
40
30
20
10
0
ATP
ADP+P
time


chemical energy
80
70
60
50
40
30
20
10
0
ADP+P
ATP
time

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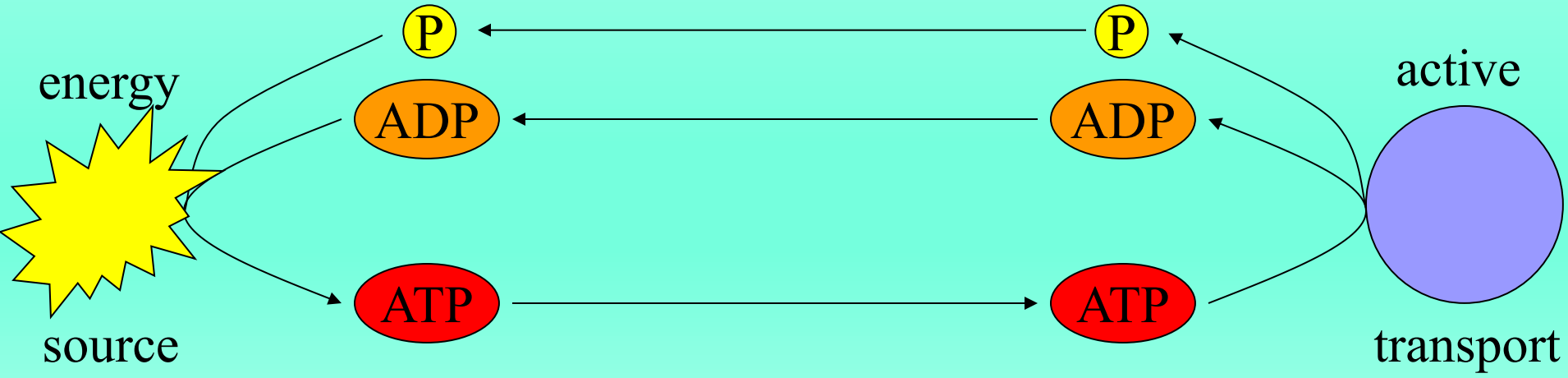


ATP (Adenosine TriPhosphate)

A high-energy molecule used to provide energy in cells.

ADP (Adenosine DiPhosphate)

The lower-energy form of ATP.

NADH (Nicotinamide Adenine Dinucleotide)
$FADH_2$ (Flavin Adenine Dinucleotide)
NADPH (Nicotinamide Adenine Dinucleotide Phosphate)

High-energy molecules (carrying high-energy electrons).

NAD^+
FAD^+
$NADP^+$

Low-energy forms of above molecules (without high-energy electrons).

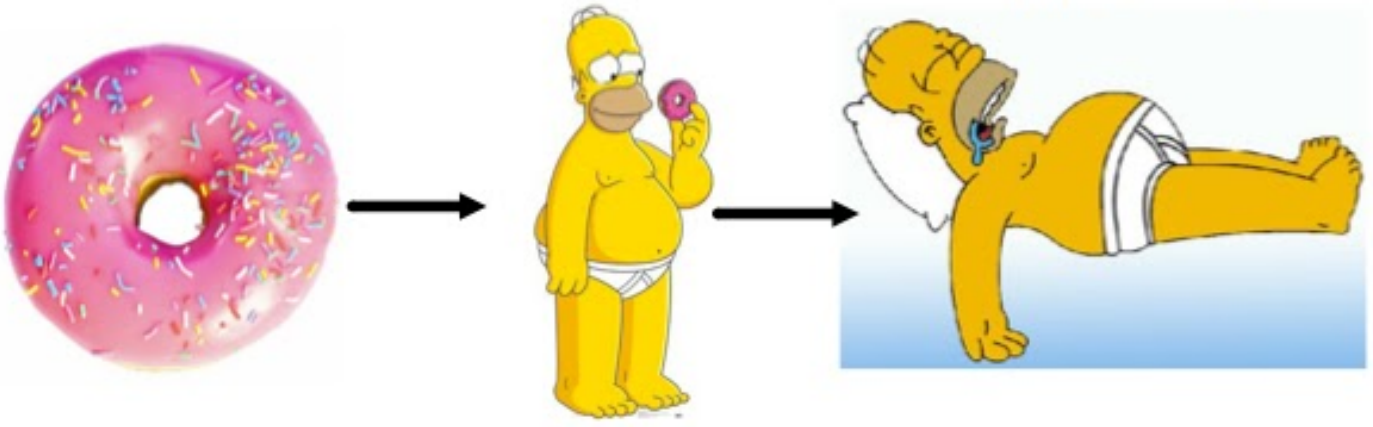
Cellular Respiration

Glycolysis
Citric acid cycle
Oxidative phosphorylation

$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$ + energy (in ATP and heat)

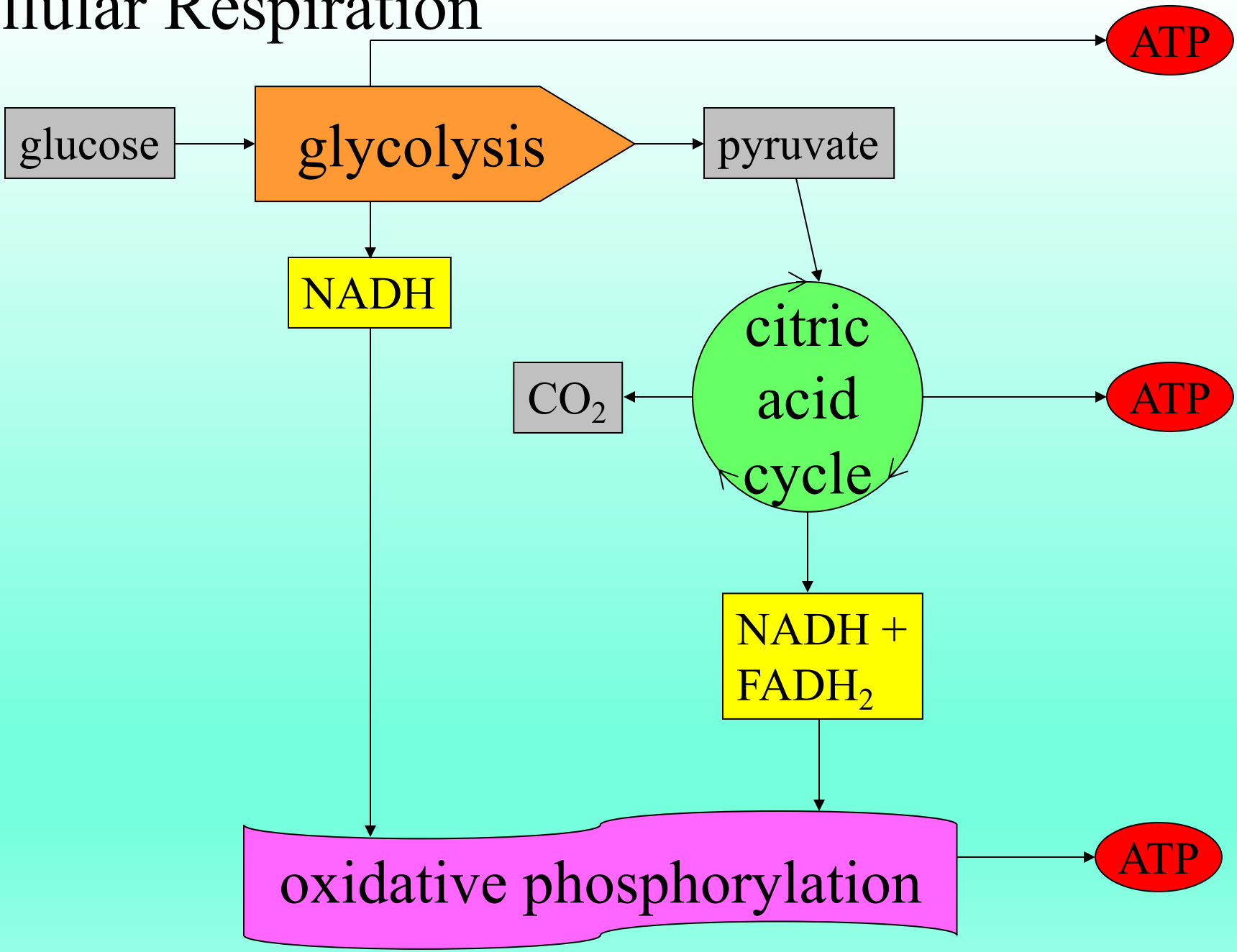
Cellular Respiration

The process in which sugars (glucose) are converted into usable energy (ATP).

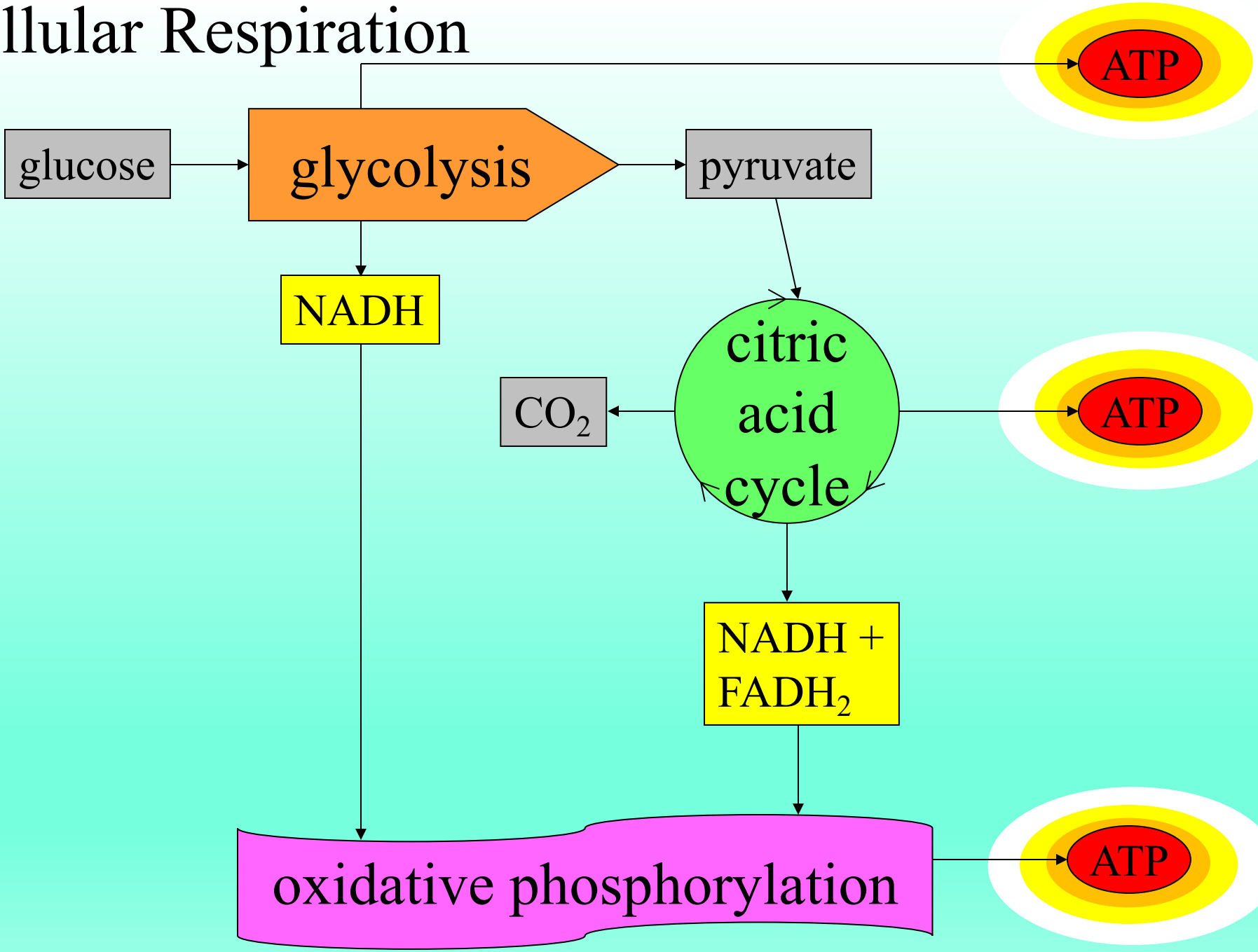


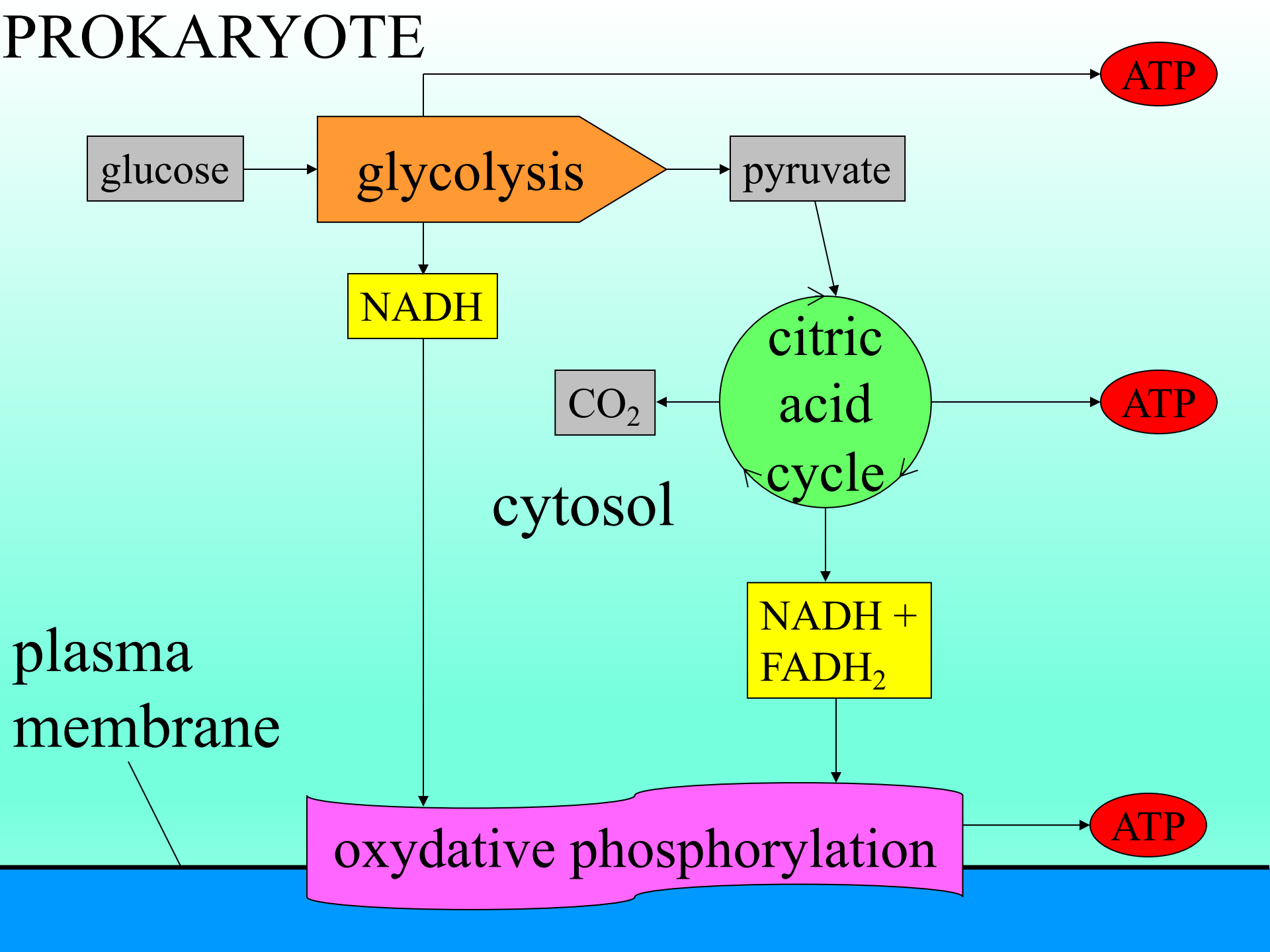
Sugar + Oxygen → Carbon Dioxide + Water + Energy

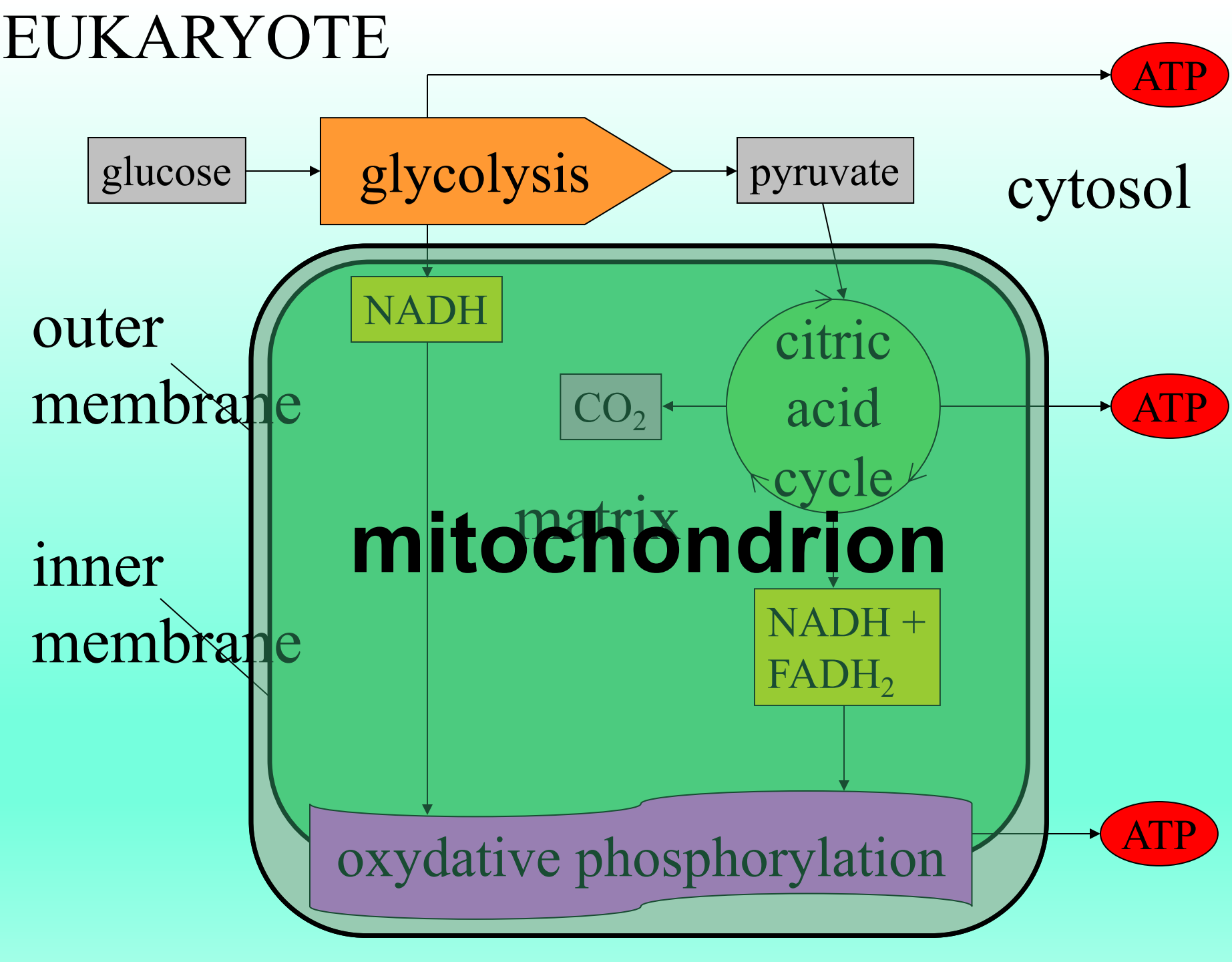
Cellular Respiration



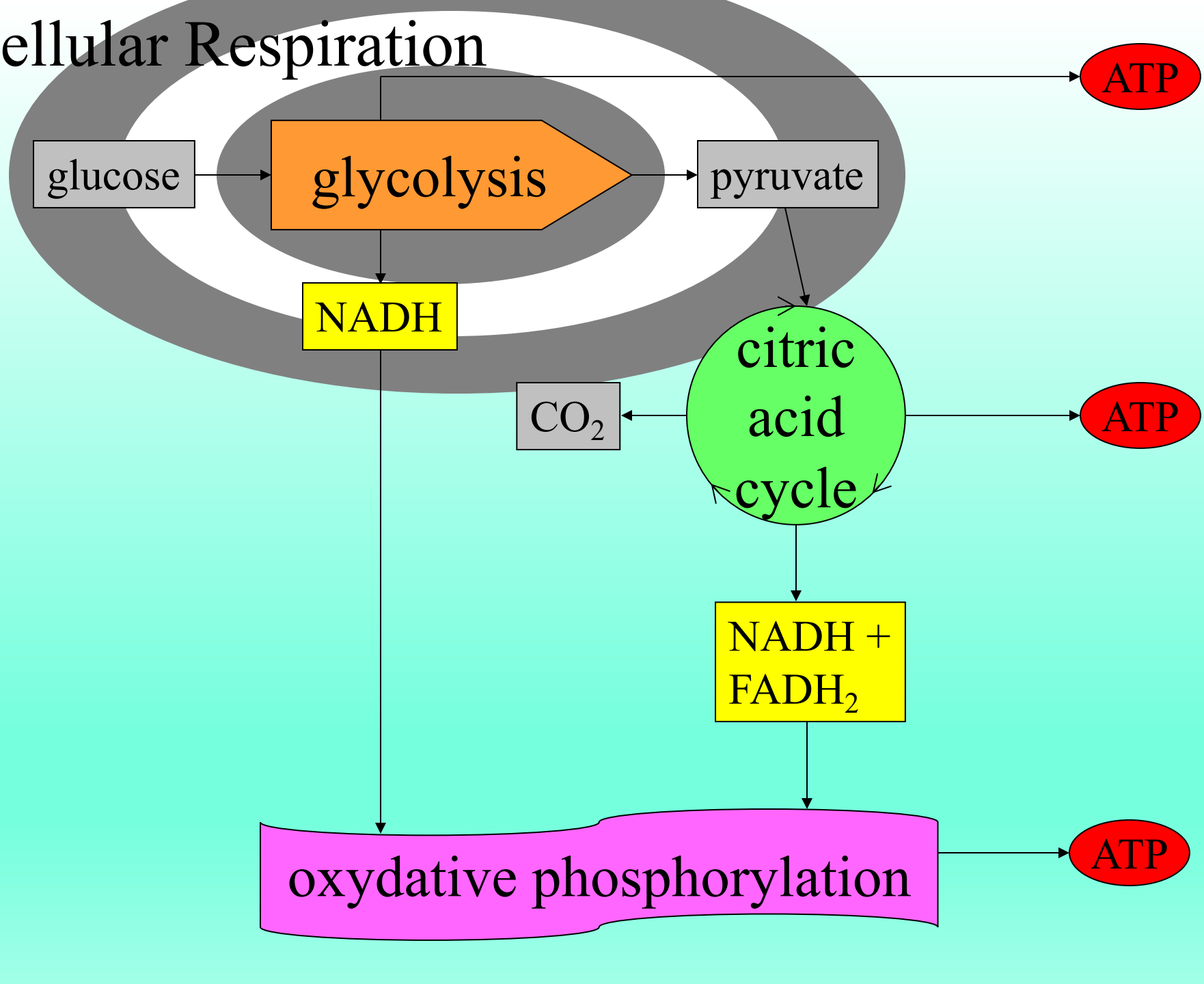
Cellular Respiration




PROKARYOTE
ATP
glucose
glycolysis
pyruvate
NADH
citric acid cycle
CO_2
ATP
cytosol
NADH + $FADH_2$
plasma membrane
oxydative phosphorylation
ATP


EUKARYOTE
ATP
glucose
glycolysis
pyruvate
cytosol
outer membrane
NADH
citric acid cycle
CO_2
ATP
matrix
mitochondrion
inner membrane
NADH + $FADH_2$
oxydative phosphorylation
ATP

Cellular Respiration



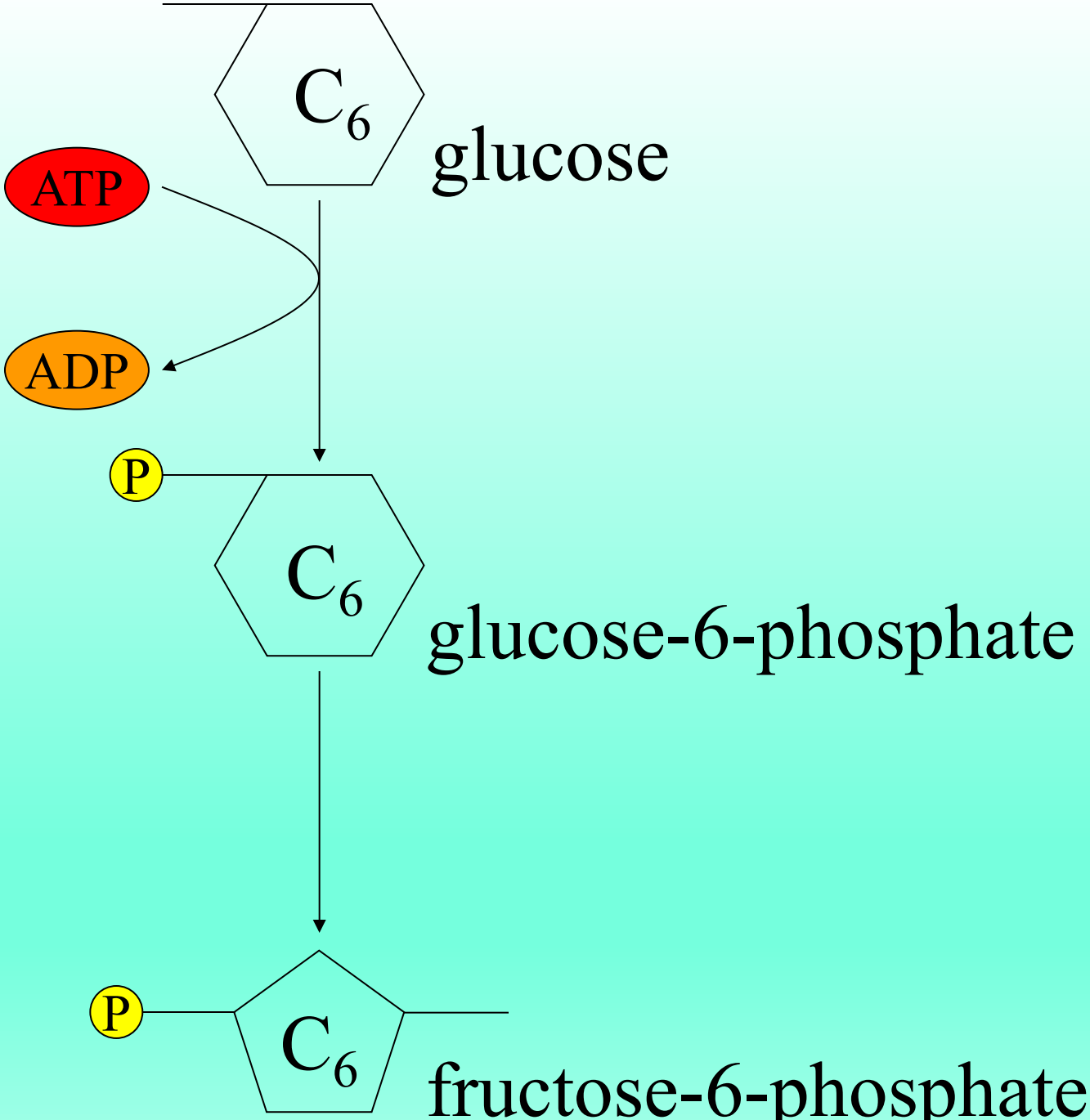
GLYCOLYSIS

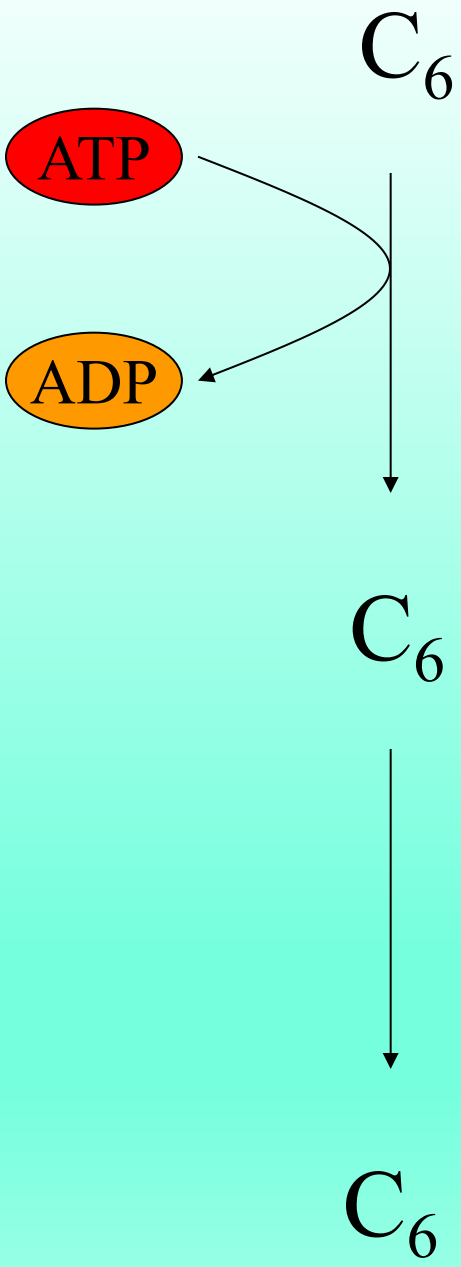
A metabolic pathway that breaks down glucose into two molecules of pyruvate.

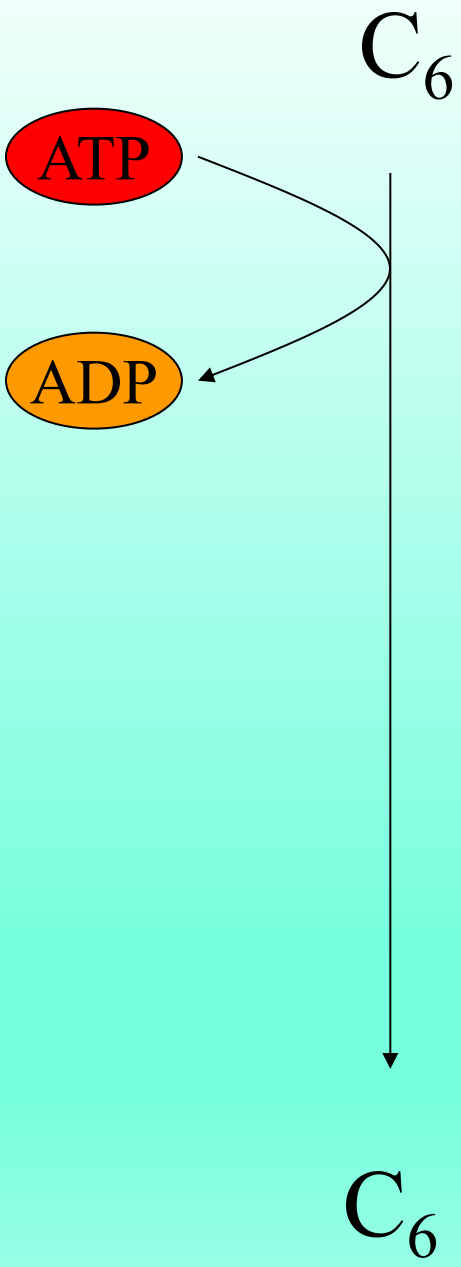
Energy released is used to change ADP to ATP and NAD^+ to NADH.

Probably one of the first energy-releasing metabolic pathway to evolve, virtually all cells conduct glycolysis in the cytosol.

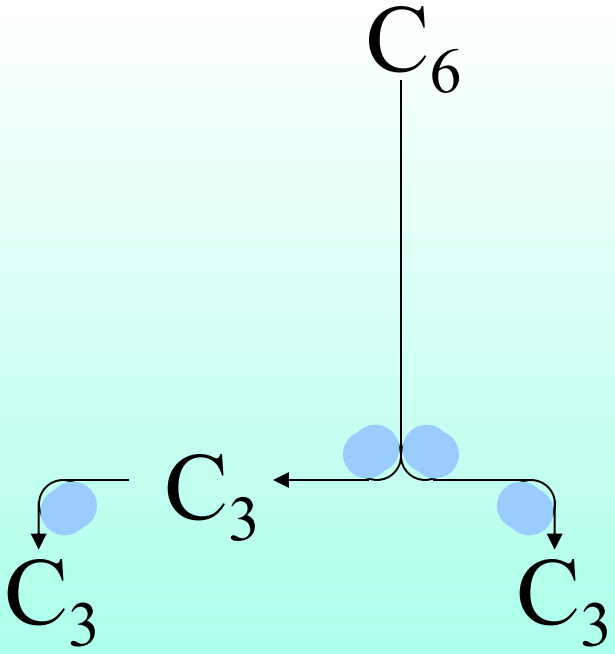
Involves 10 steps (chemical reactions), each with its own enzyme.


C6
glucose
ATP
ADP
P
C6
glucose-6-phosphate
P
C6
fructose-6-phosphate


C_6
ATP
ADP
C_6
C_6


C_6
ATP
ADP
C_6

Glycolysis

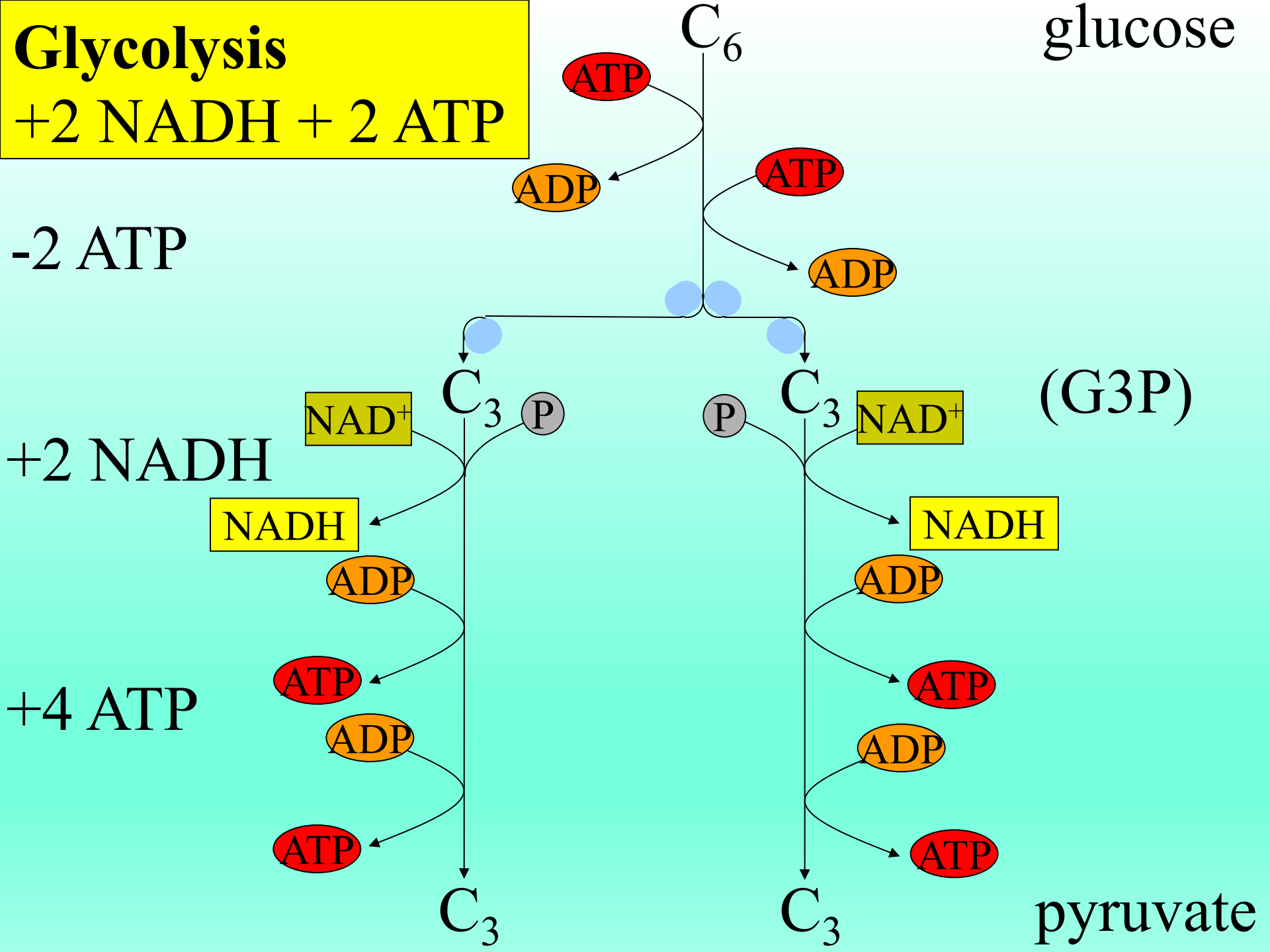


glucose

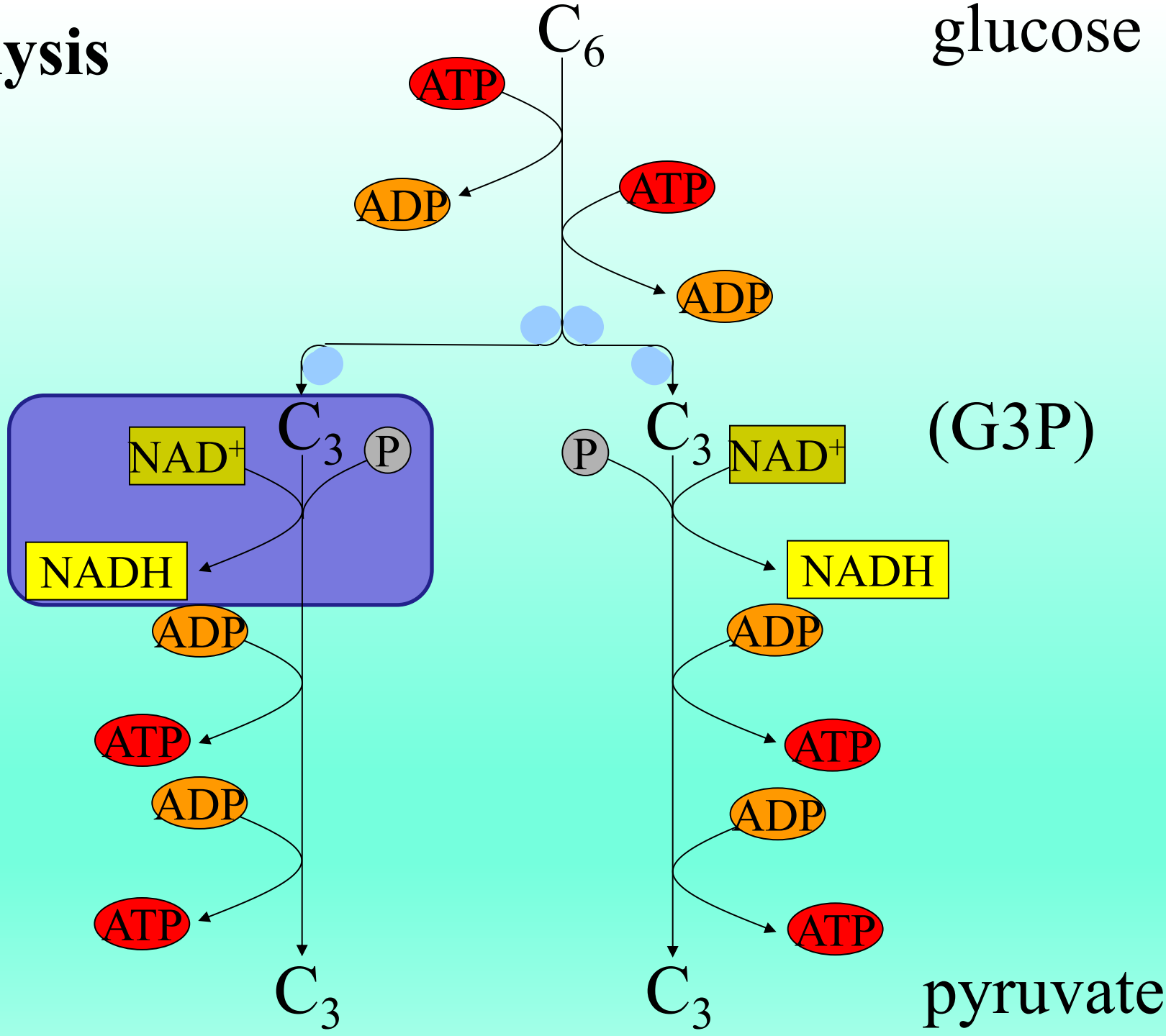
CYTOSOL

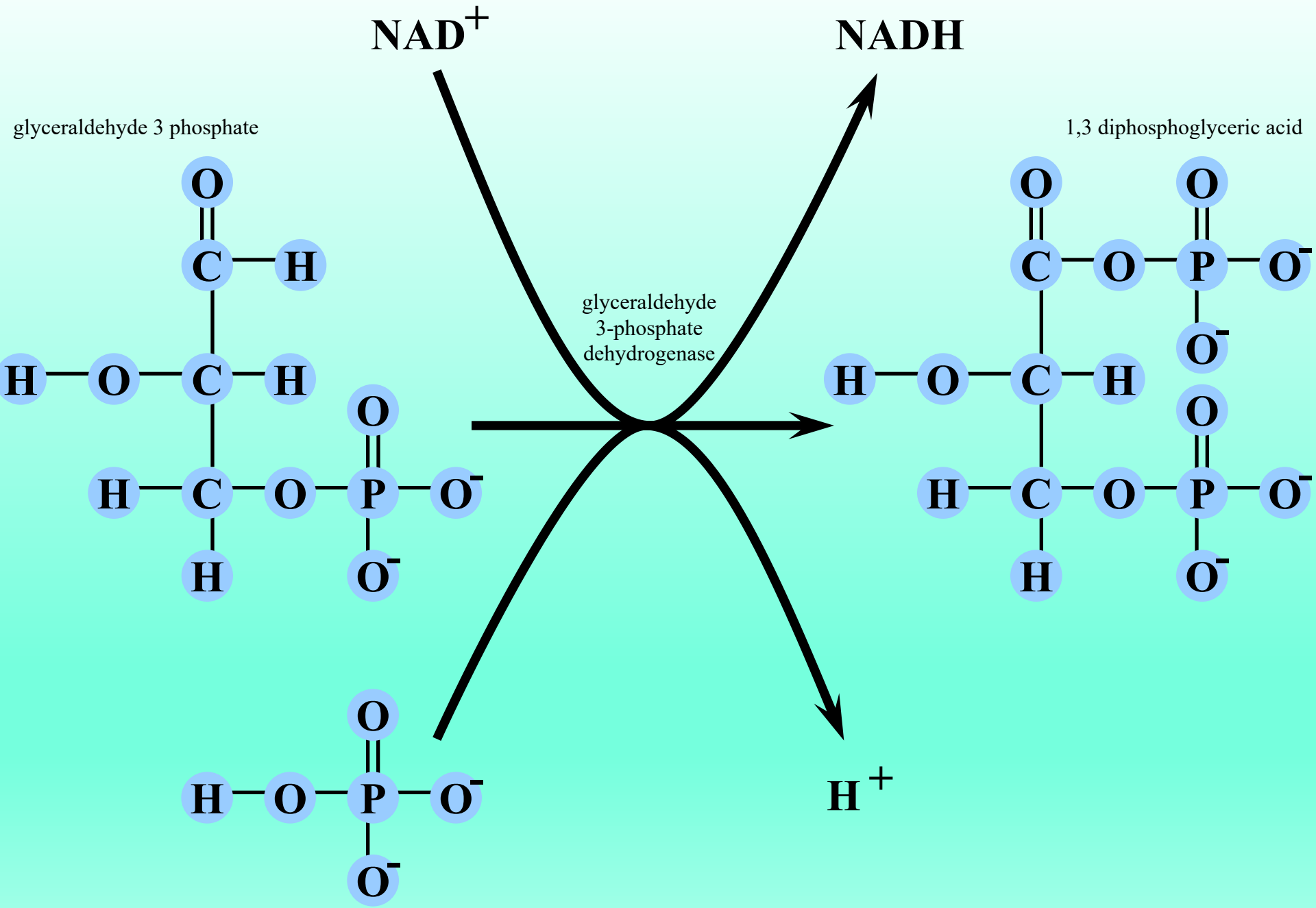
(G3P)

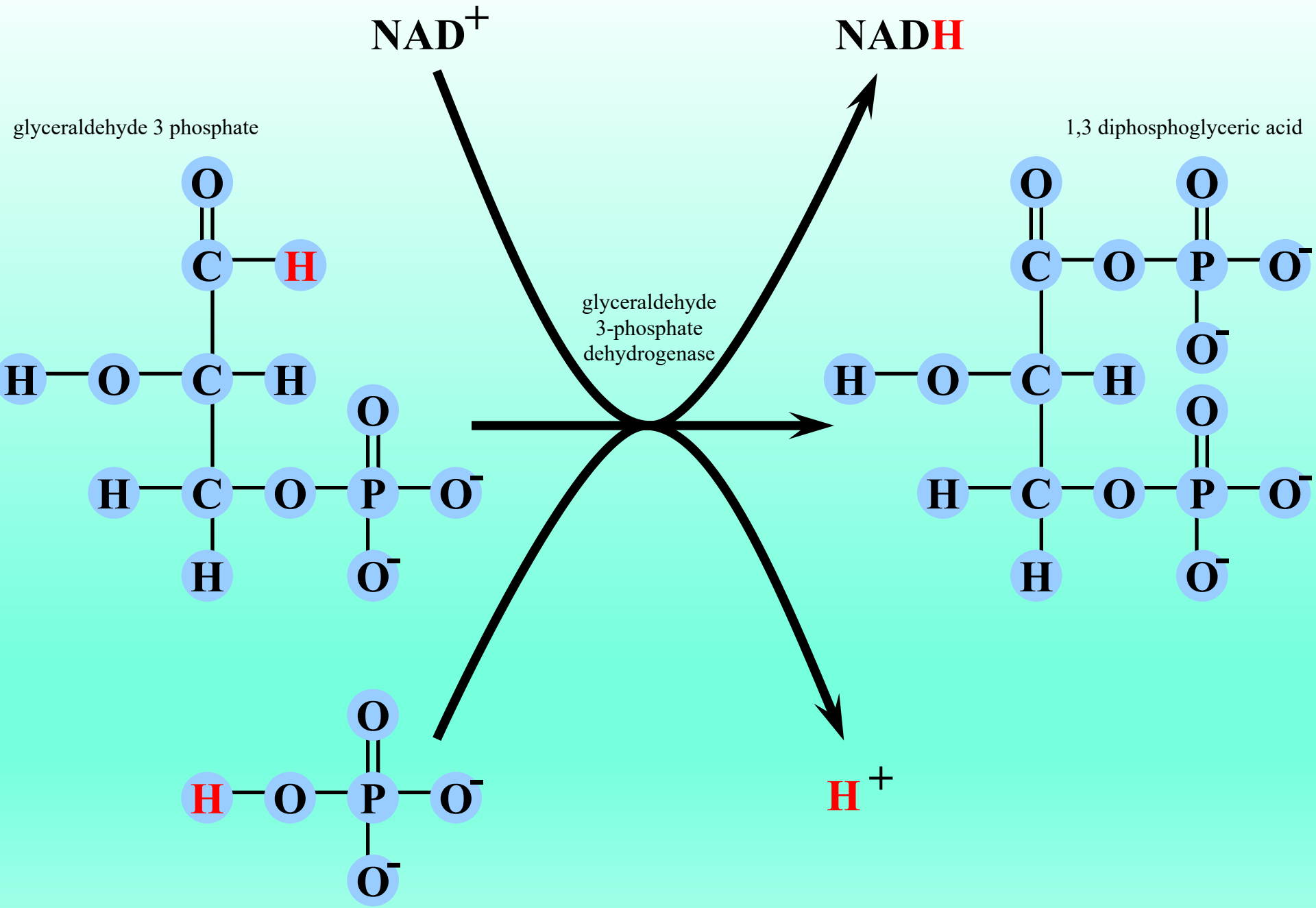
*Occurs regardless of O2 presence


Glycolysis
+2 NADH + 2 ATP
-2 ATP
+2 NADH
+4 ATP
C6
glucose
ATP
ADP
ATP
ADP
C3
P
NAD+
(G3P)
NADH
ADP
ATP
ADP
ATP
C3
pyruvate

Glycolysis


C6
glucose
ATP
ADP
ATP
ADP
C3
NAD+
P
NADH
C3
P
NAD+
NADH
(G3P)
ADP
ATP
ADP
ATP
ADP
ATP
C3
C3
pyruvate


NAD+
NADH
glyceraldehyde 3 phosphate
1,3 diphosphoglyceric acid
glyceraldehyde
3-phosphate
dehydrogenase
H+


NAD+
NADH
glyceraldehyde 3 phosphate
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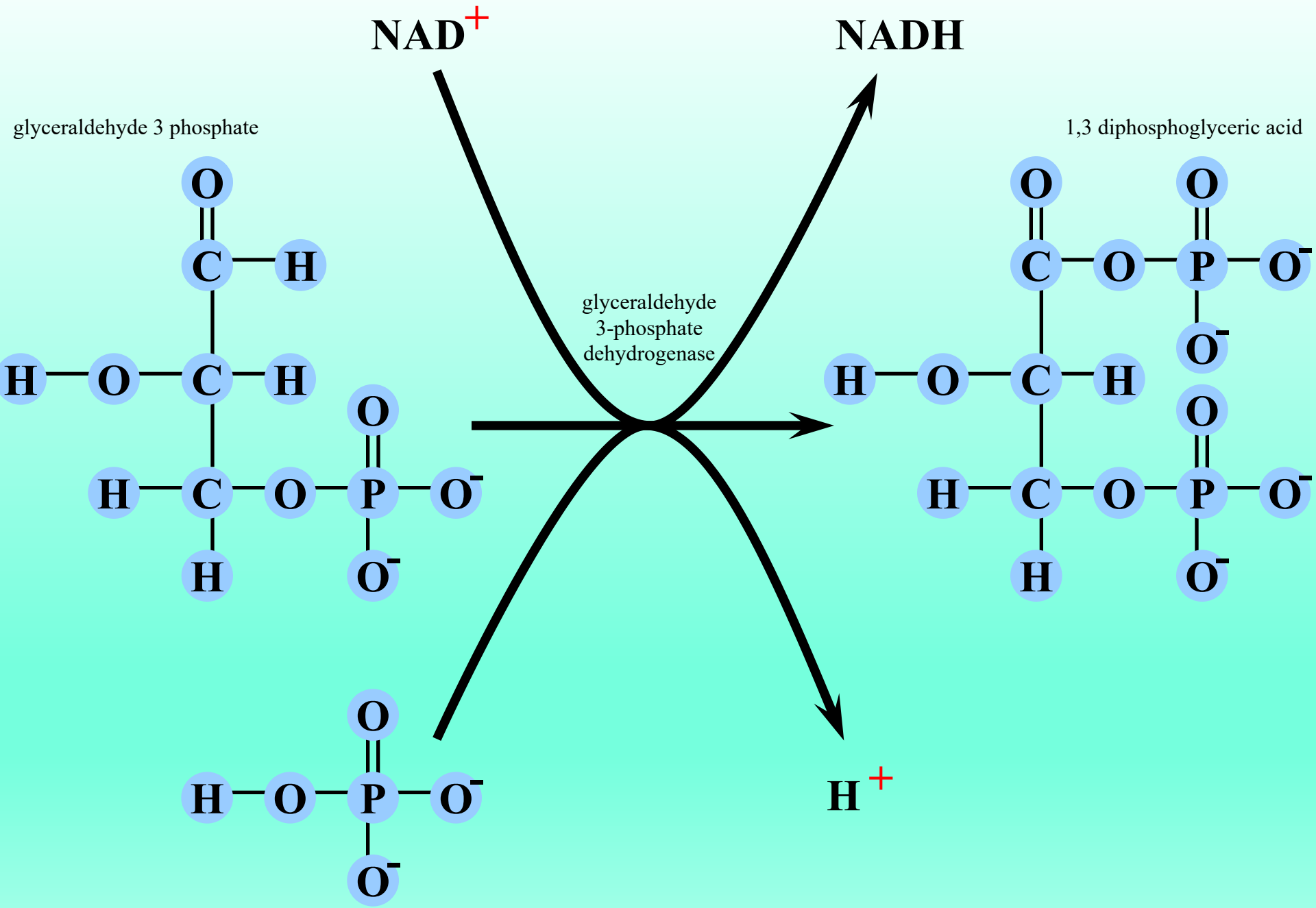
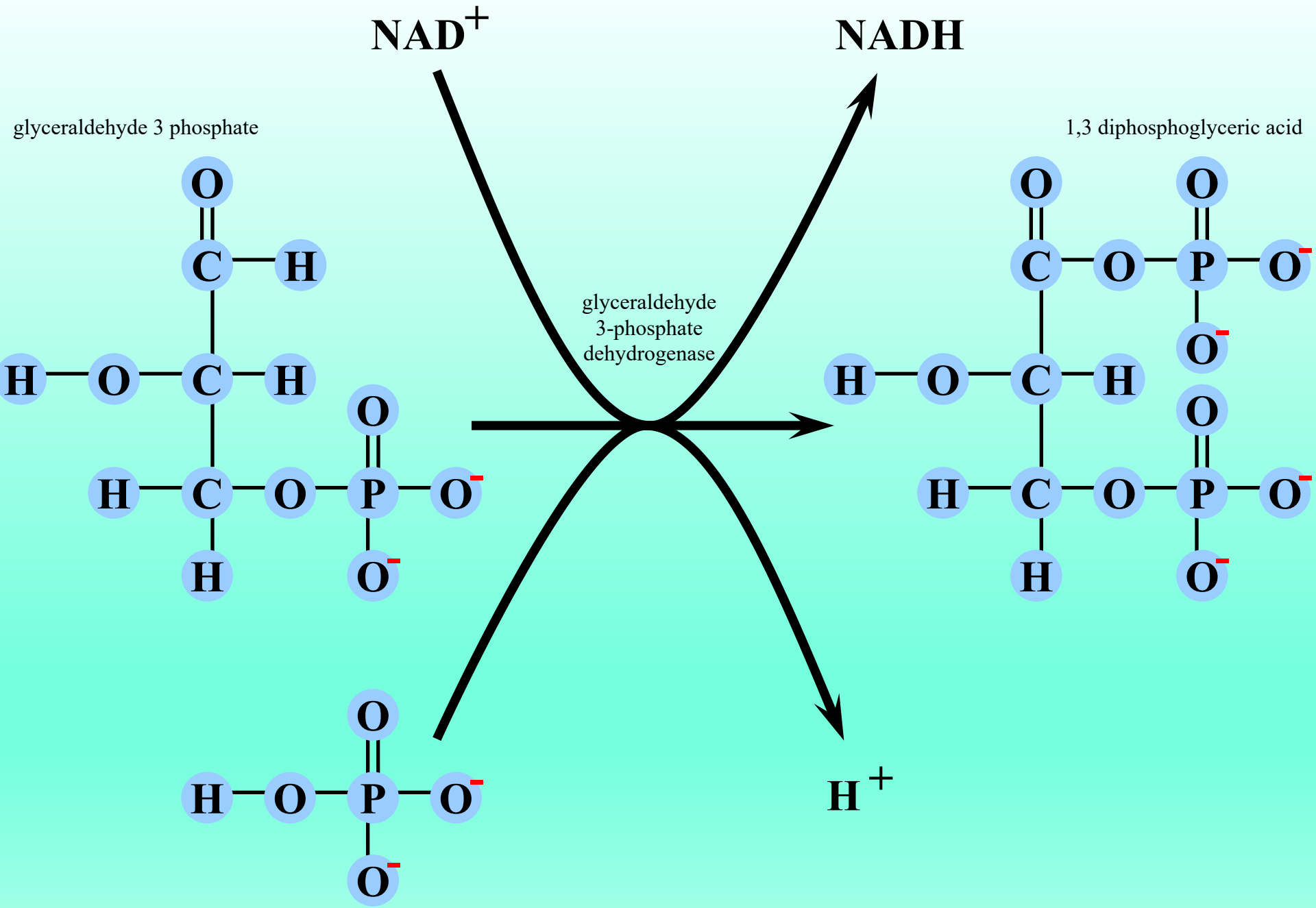
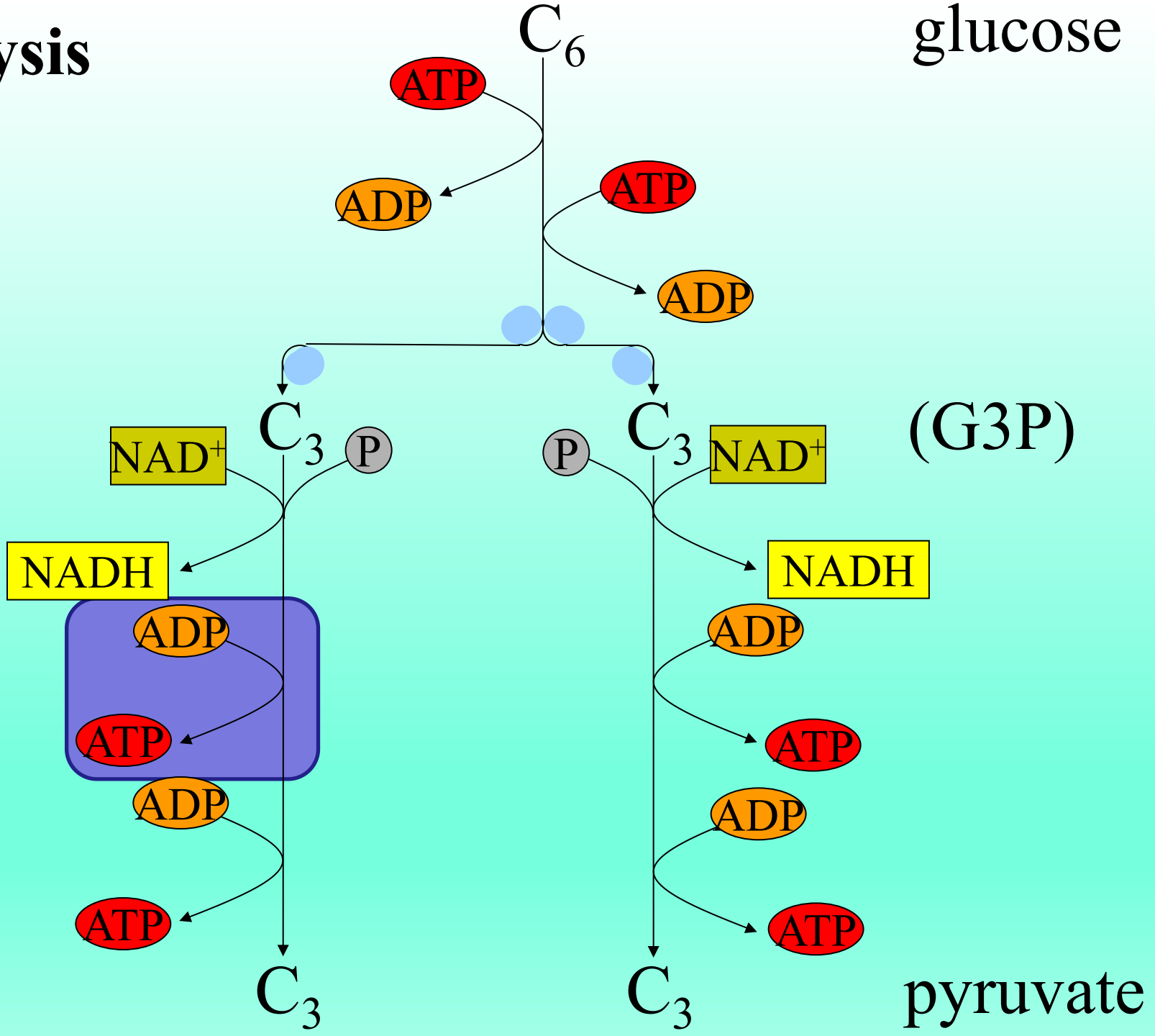
glyceraldehyde
3-phosphate
dehydrogenase
H+

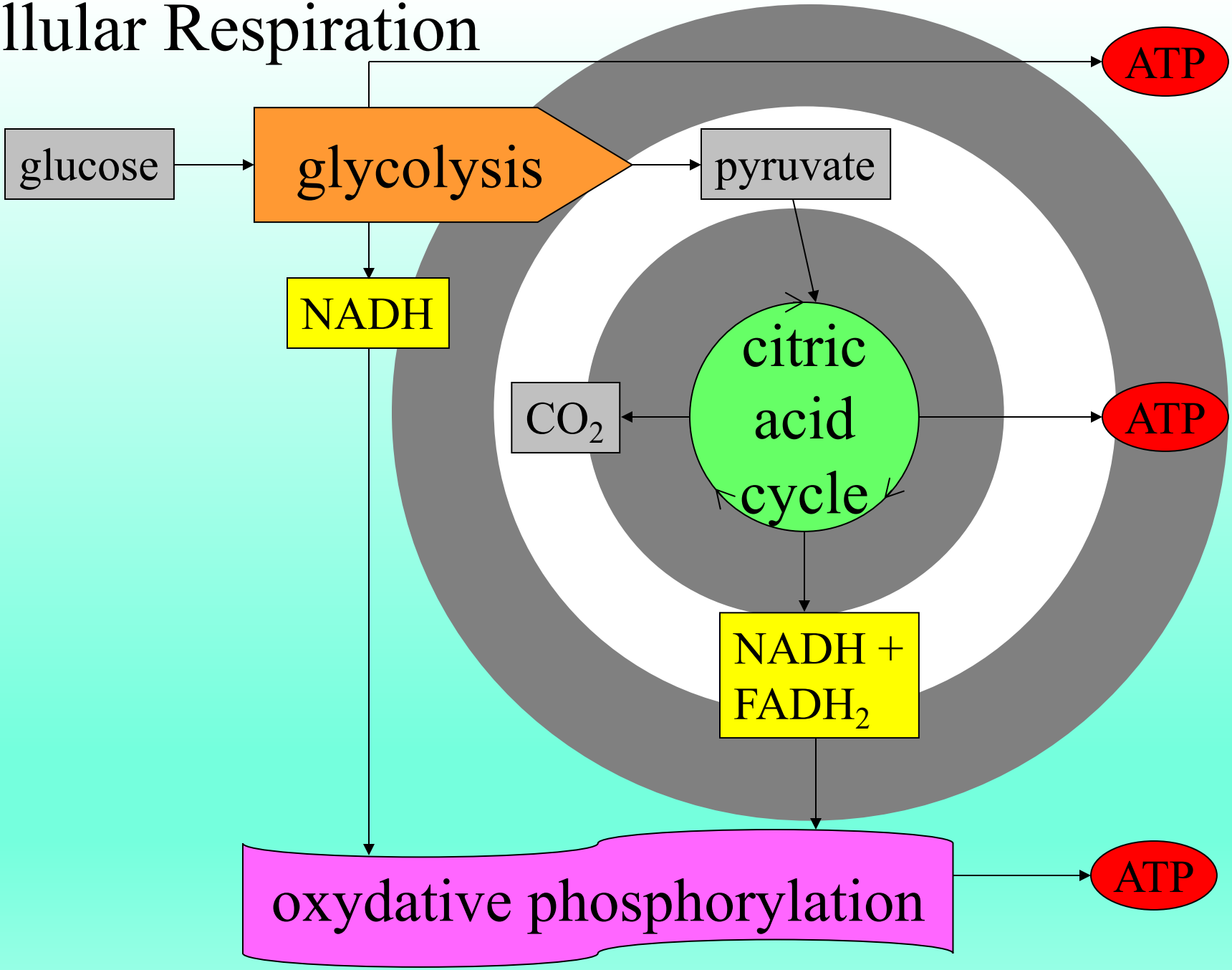

NAD+
NADH
glyceraldehyde 3 phosphate
1,3 diphosphoglyceric acid
glyceraldehyde
3-phosphate
dehydrogenase
H+


NAD+
NADH
glyceraldehyde 3 phosphate
1,3 diphosphoglyceric acid
glyceraldehyde
3-phosphate
dehydrogenase
H+

Glycolysis


C6
glucose
ATP
ADP
ATP
ADP
C3
P
NAD+
NADH
(G3P)
P
C3
NAD+
NADH
ADP
ATP
ADP
ATP
ADP
ATP
C3
C3
pyruvate

Cellular Respiration



THE CITRIC ACID CYCLE

THE KREBS CYCLE

THE TRICARBOXILIC ACID CYCLE

A cyclical metabolic pathway that breaks down pyruvate into 3 CO_2.

Energy released is used to change ADP to ATP, NAD^+ to NADH, and FAD^+ to $FADH_2$.

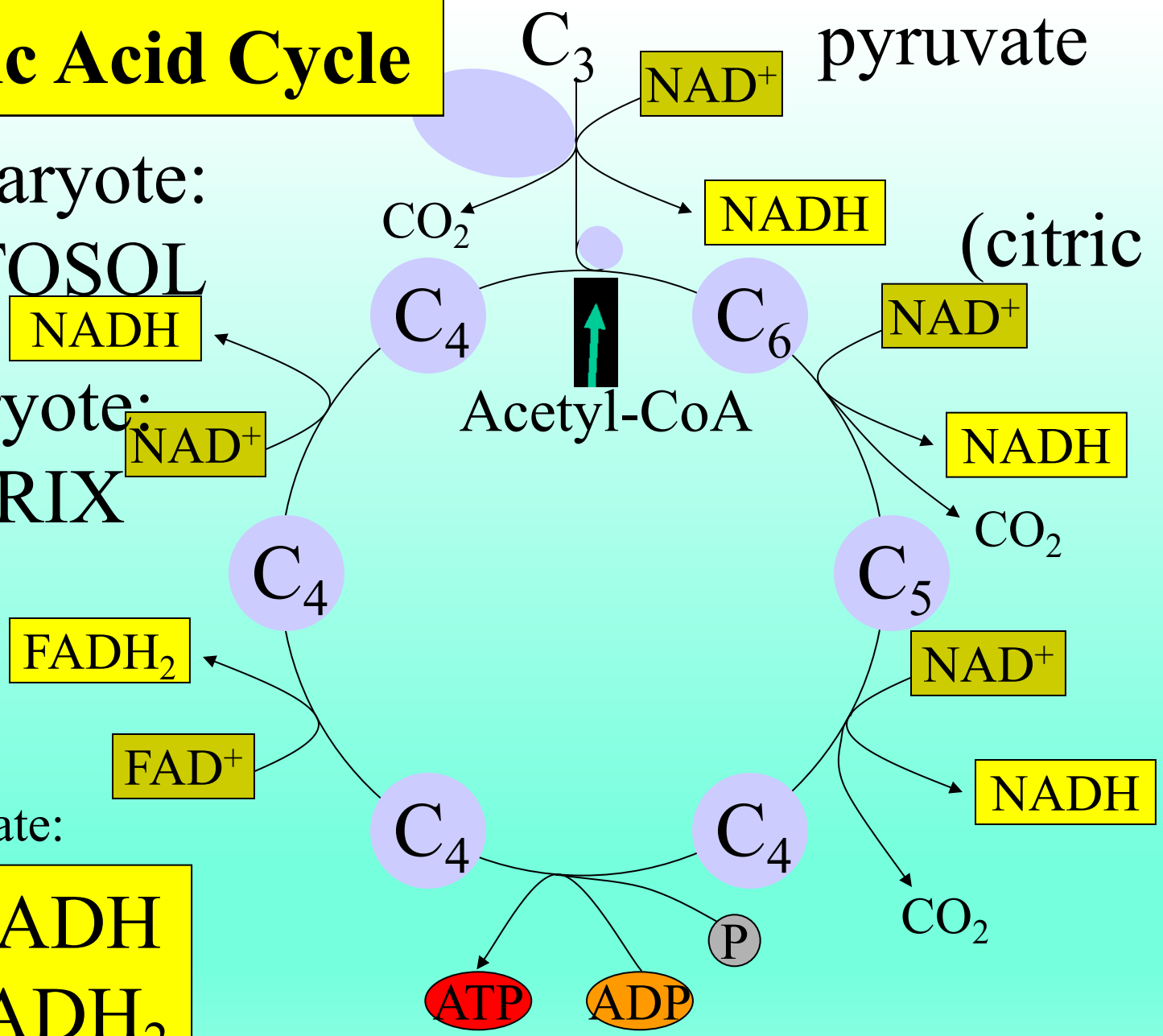
Pyruvate is changed (into Acetyl-CoA) through three reactions before entering this cycle, not detailed here.

Involves 11 chemical reactions, each with its own enzyme.

Citric Acid Cycle

prokaryote:
CYTOSOL

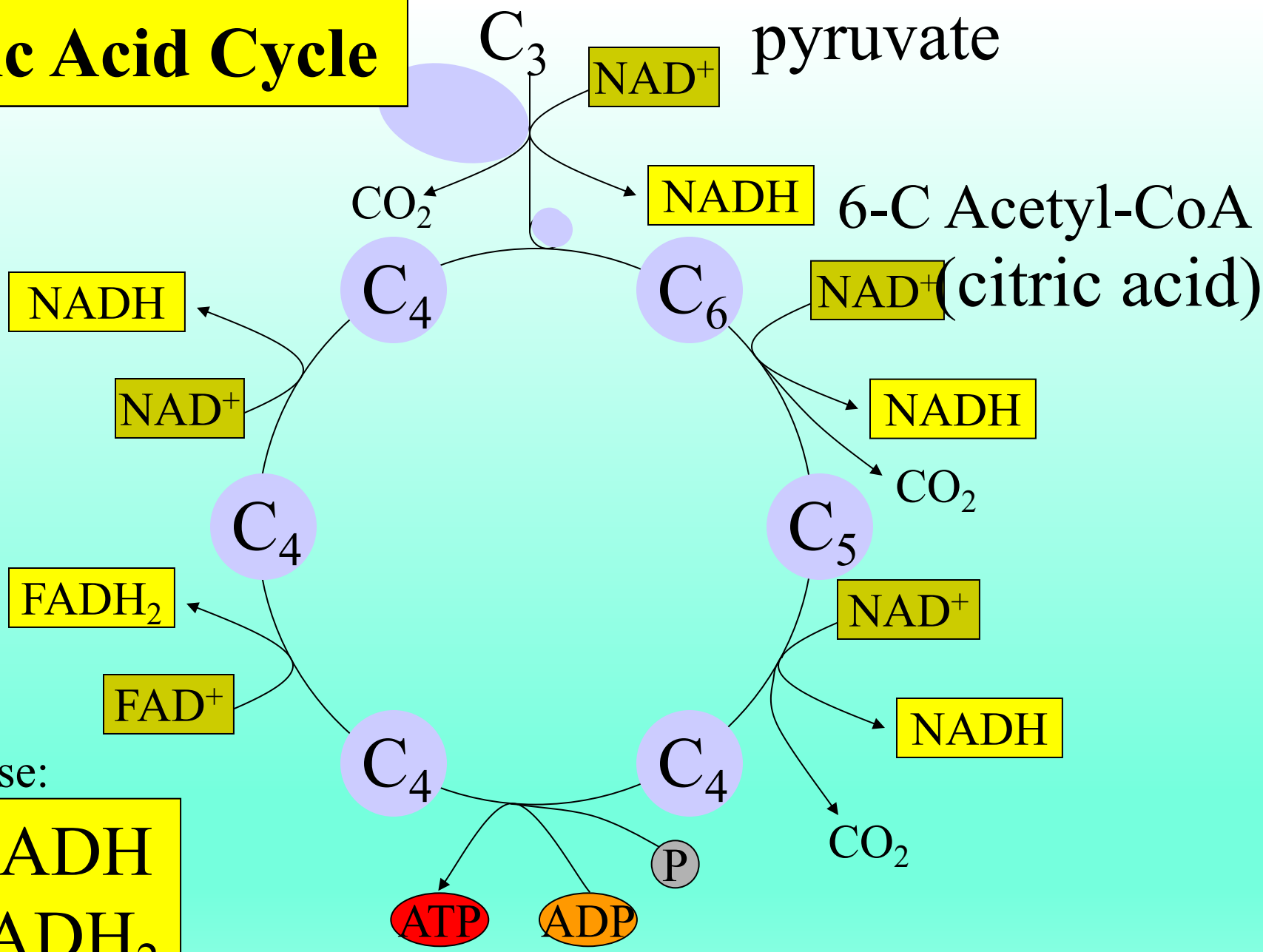
eukaryote:
MATRIX



from
1 pyruvate:

+4 NADH
+1 $FADH_2$
+1 ATP

Citric Acid Cycle

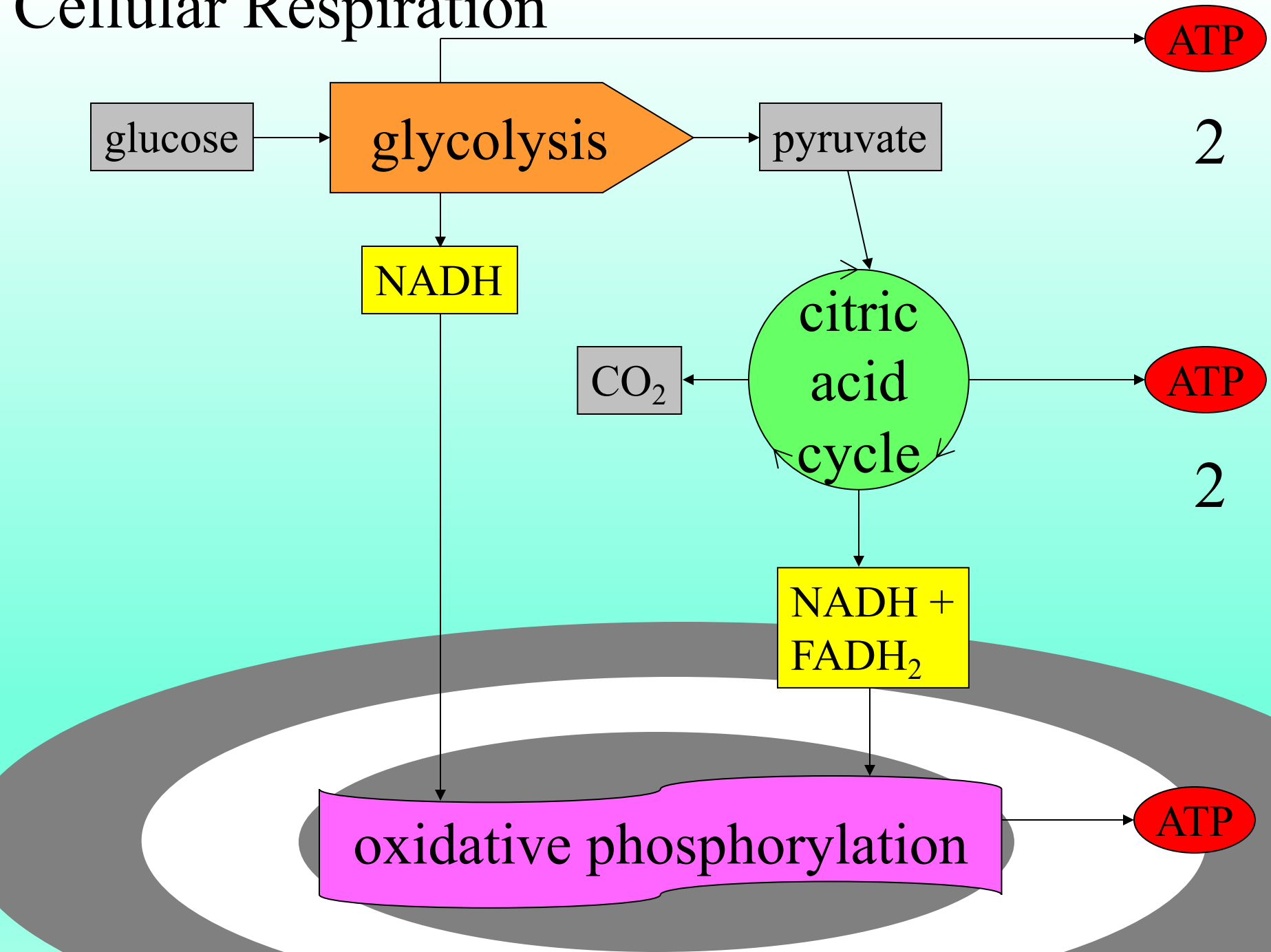


from
1 glucose:

+8 NADH
+2 $FADH_2$
+2 ATP

Citric Acid Song

Cellular Respiration



OXYDATIVE PHOSPHORYLATION

A chain of molecules uses energy from NADH and $FADH_2$ to generate a H^+ (proton) gradient.

The H^+ gradient is used to change ADP to ATP.

Involves 10 electron carriers (9 are proteins), plus ATP synthase.

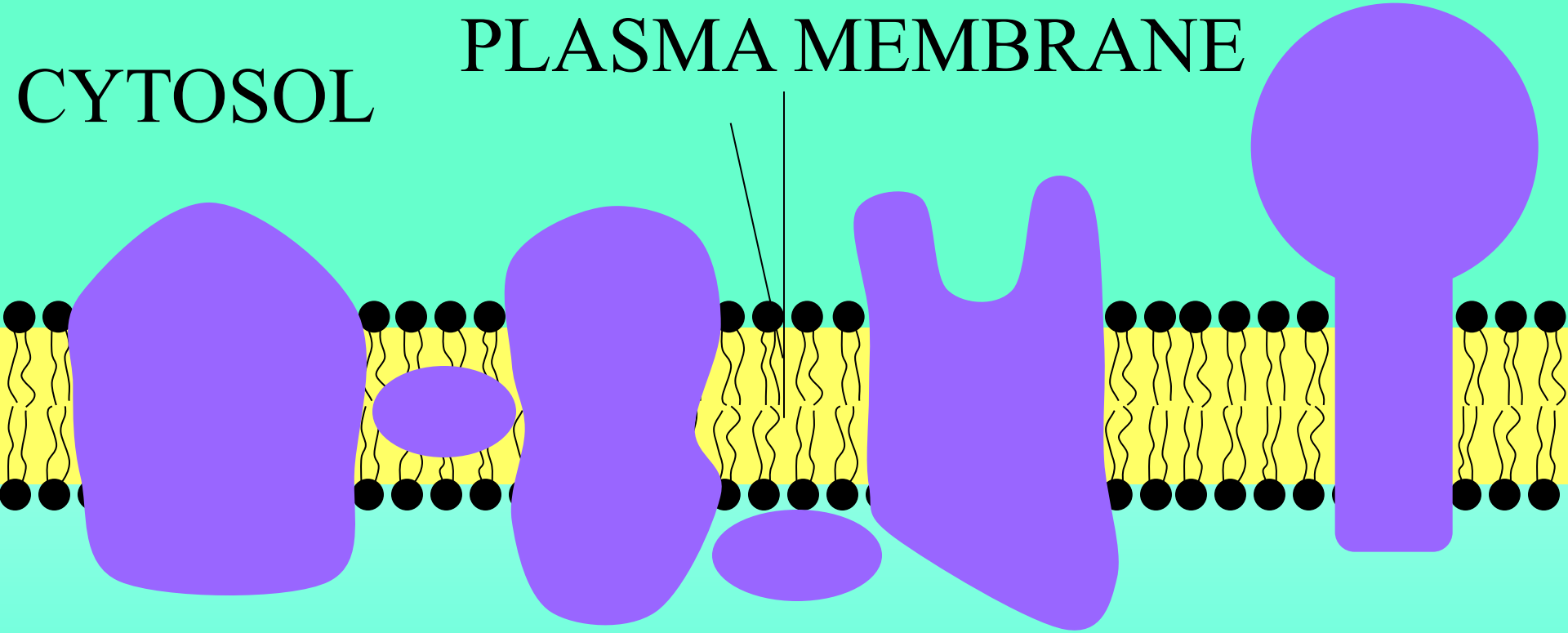
Oxydative Phosphorylation

The Electron Transport Chain

PROKARYOTE

PLASMA MEMBRANE

CYTOSOL



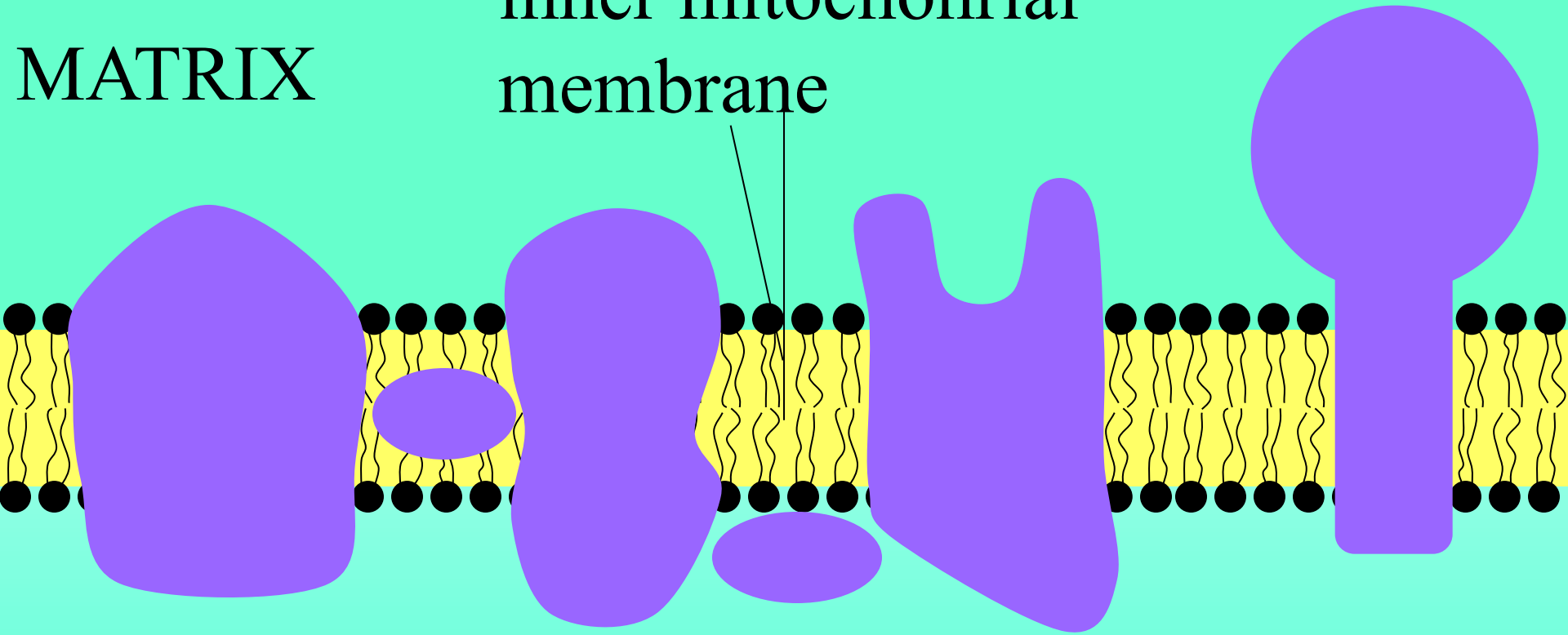
ENVIRONMENT

Oxydative Phosphorylation

EUKARYOTE

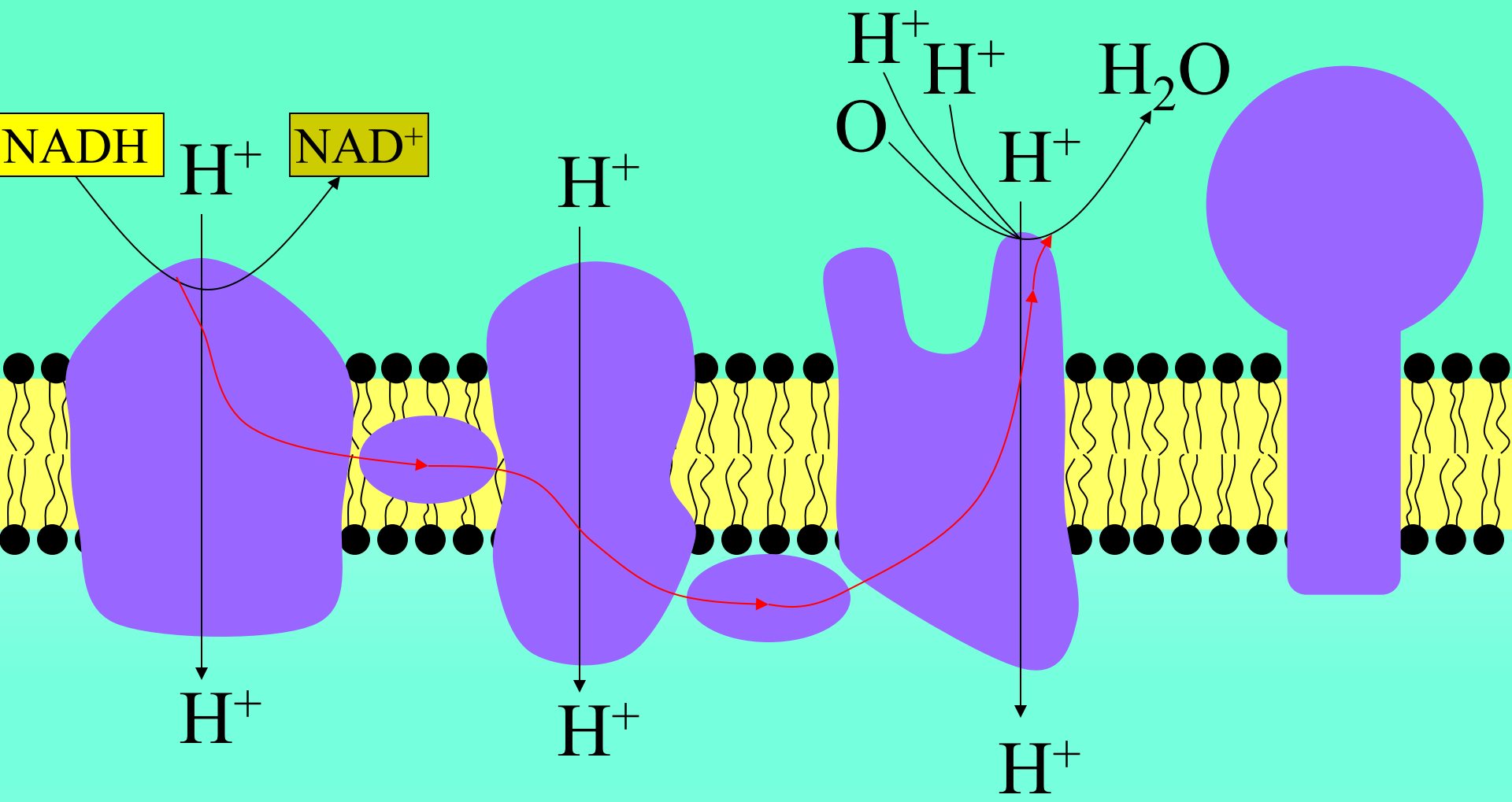
MATRIX

inner mitochonrial membrane

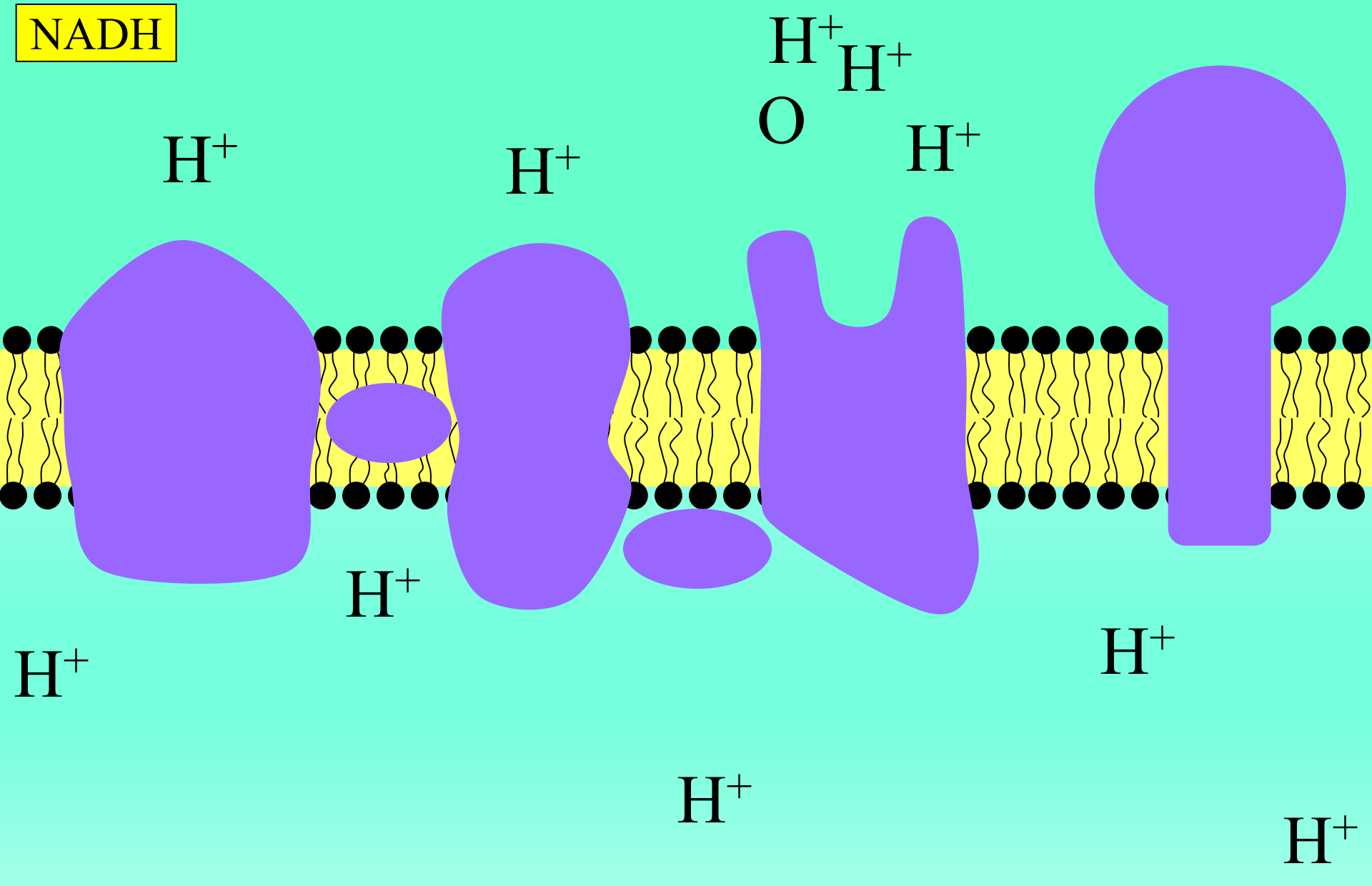


fluid between outer and inner membranes

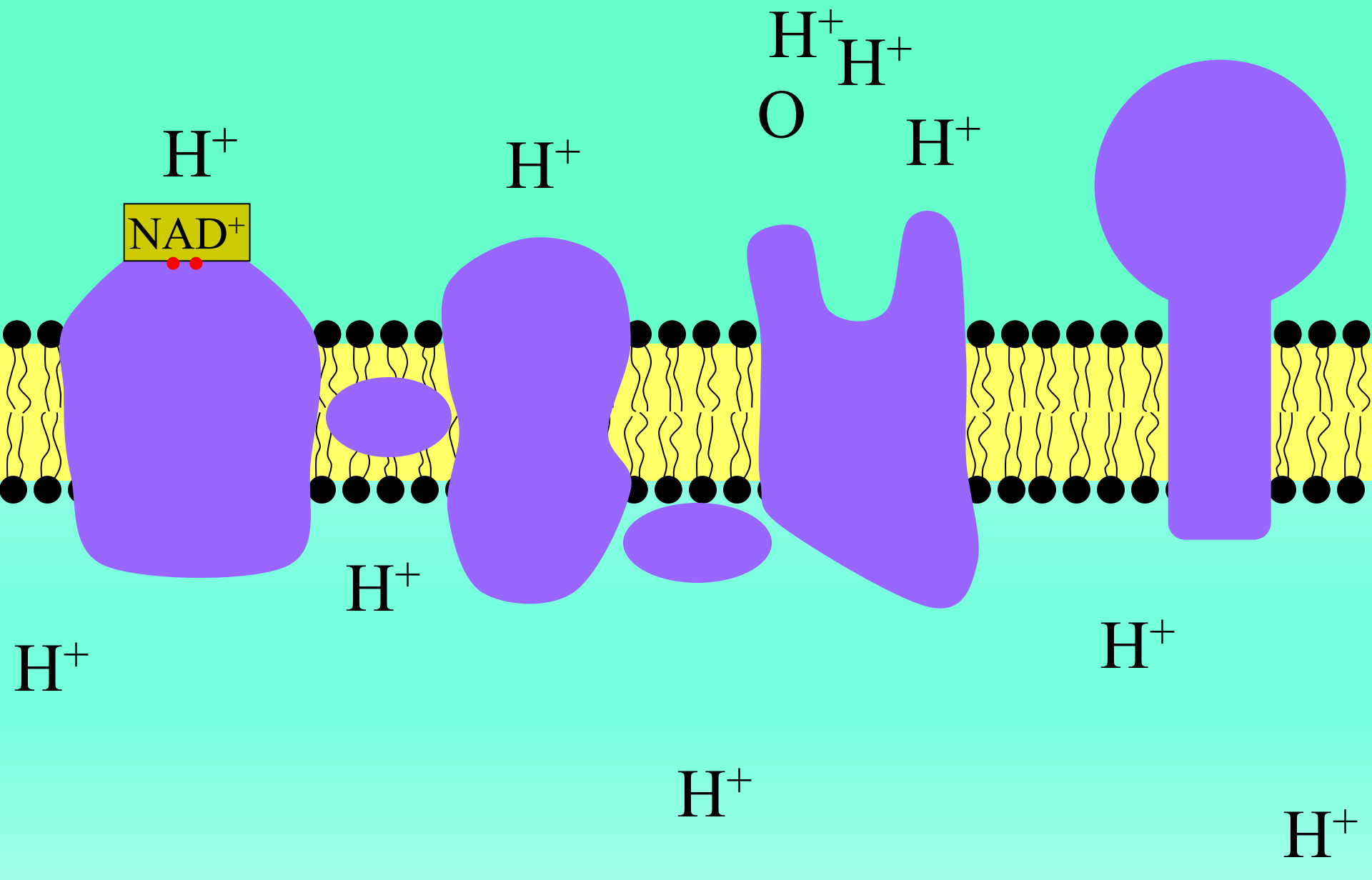
The Electron Transport Chain



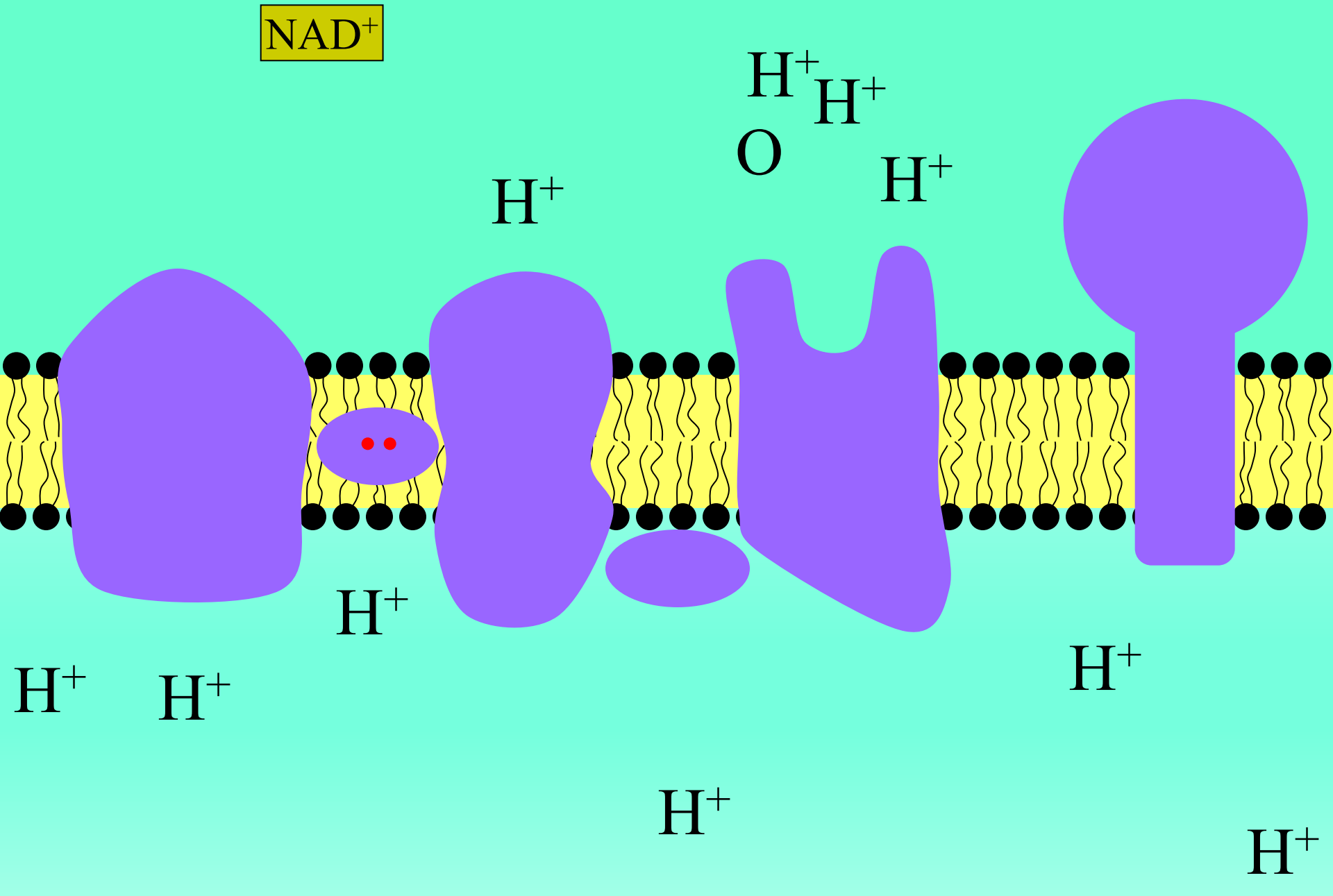
The Electron Transport Chain



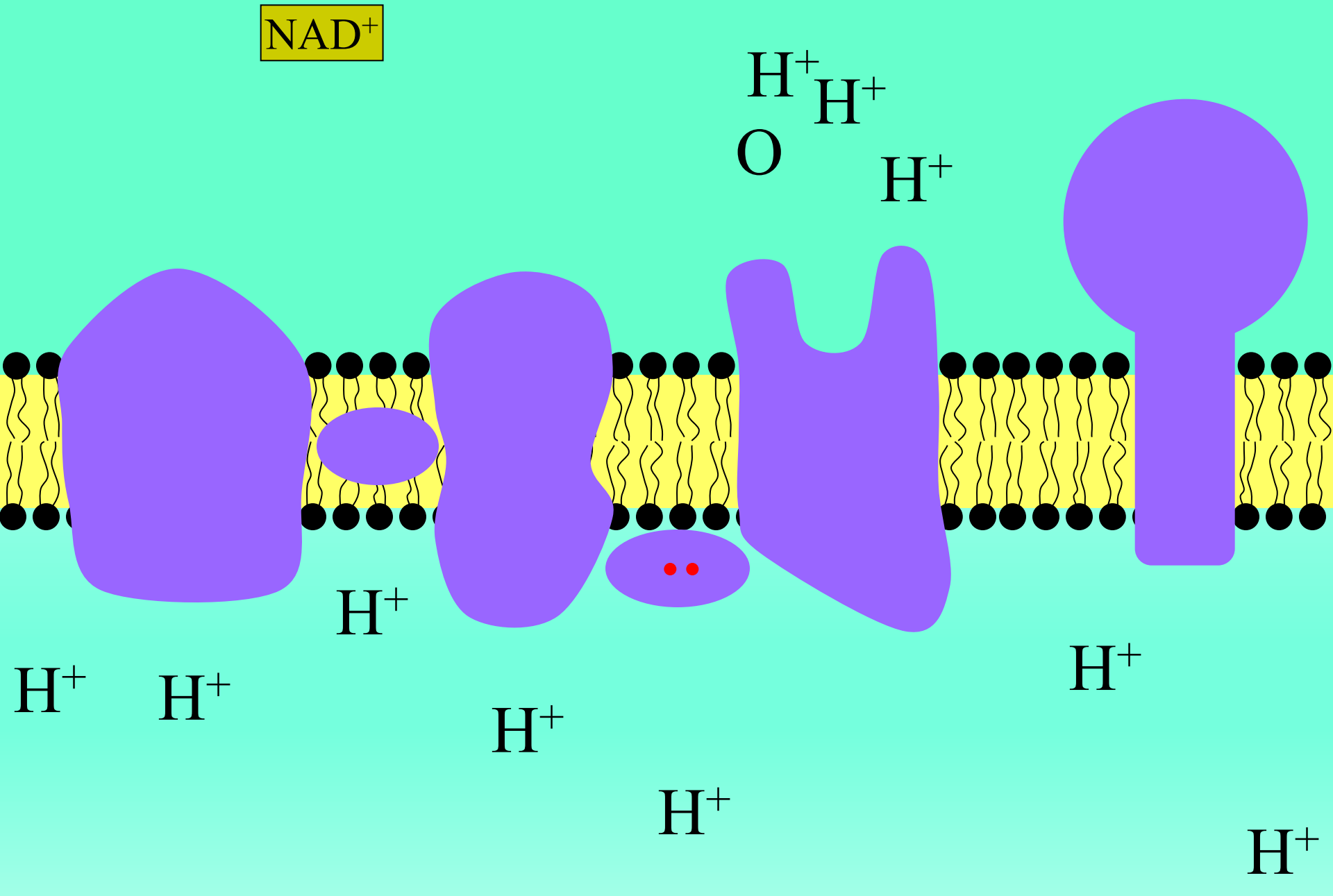
The Electron Transport Chain



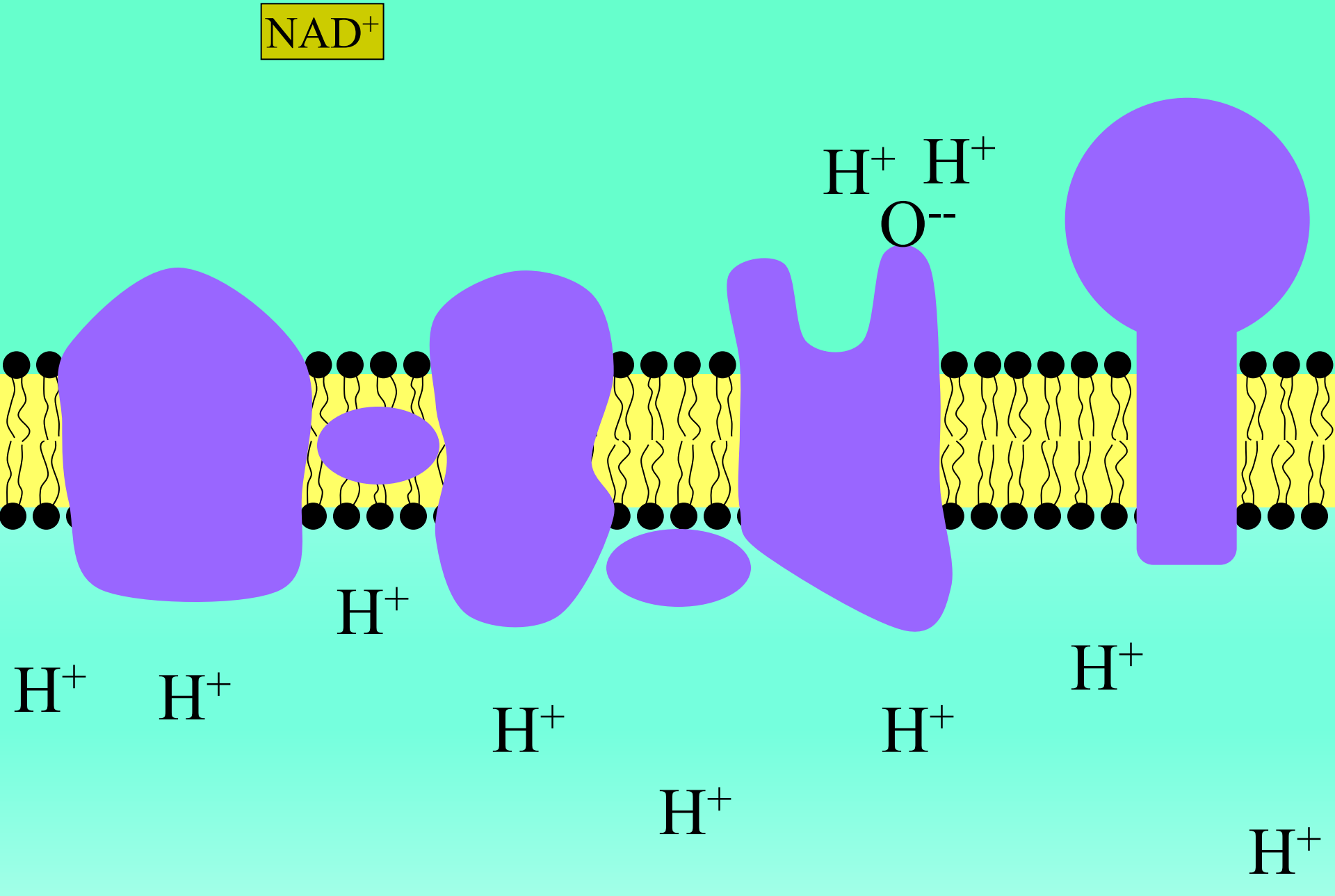
The Electron Transport Chain



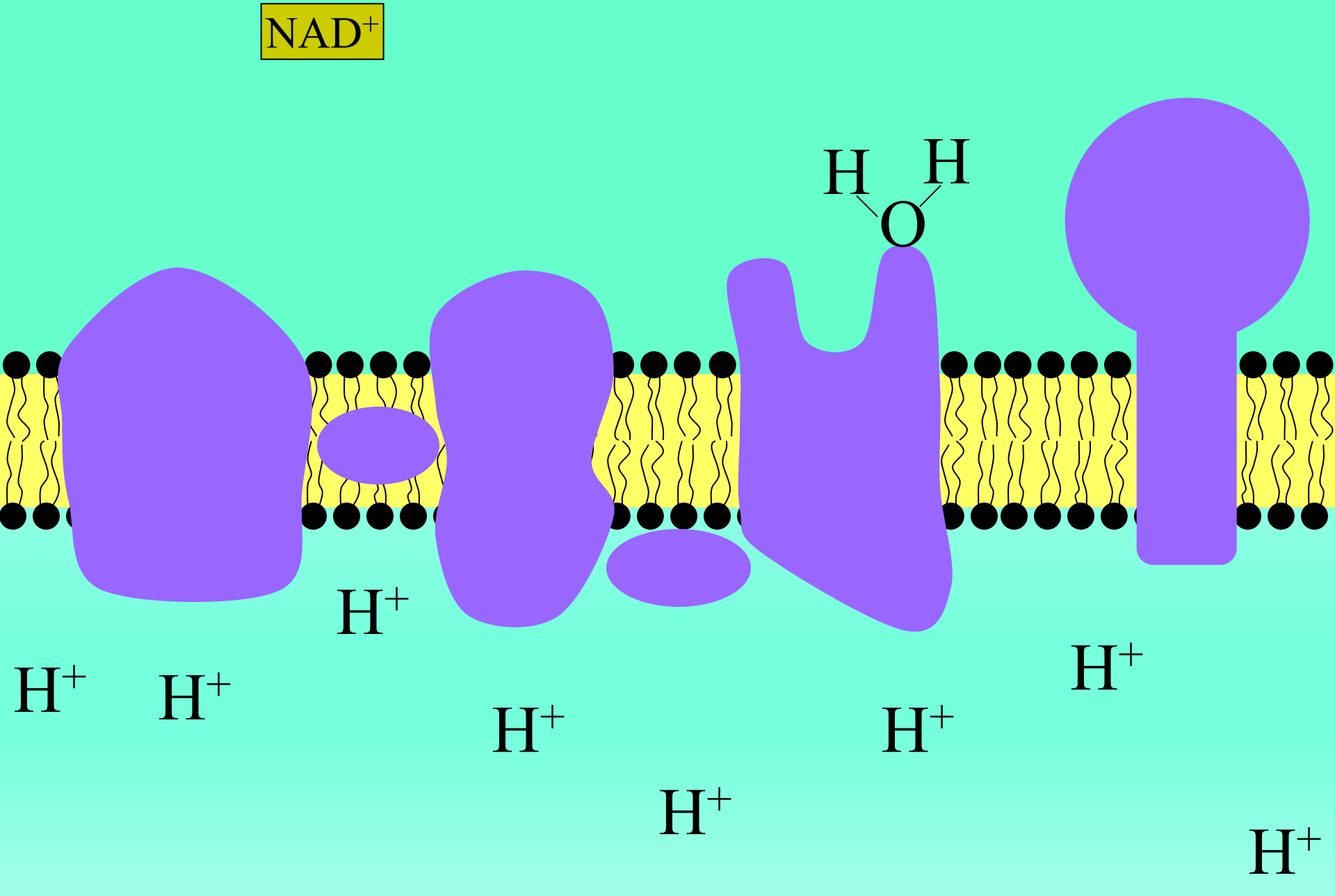
The Electron Transport Chain



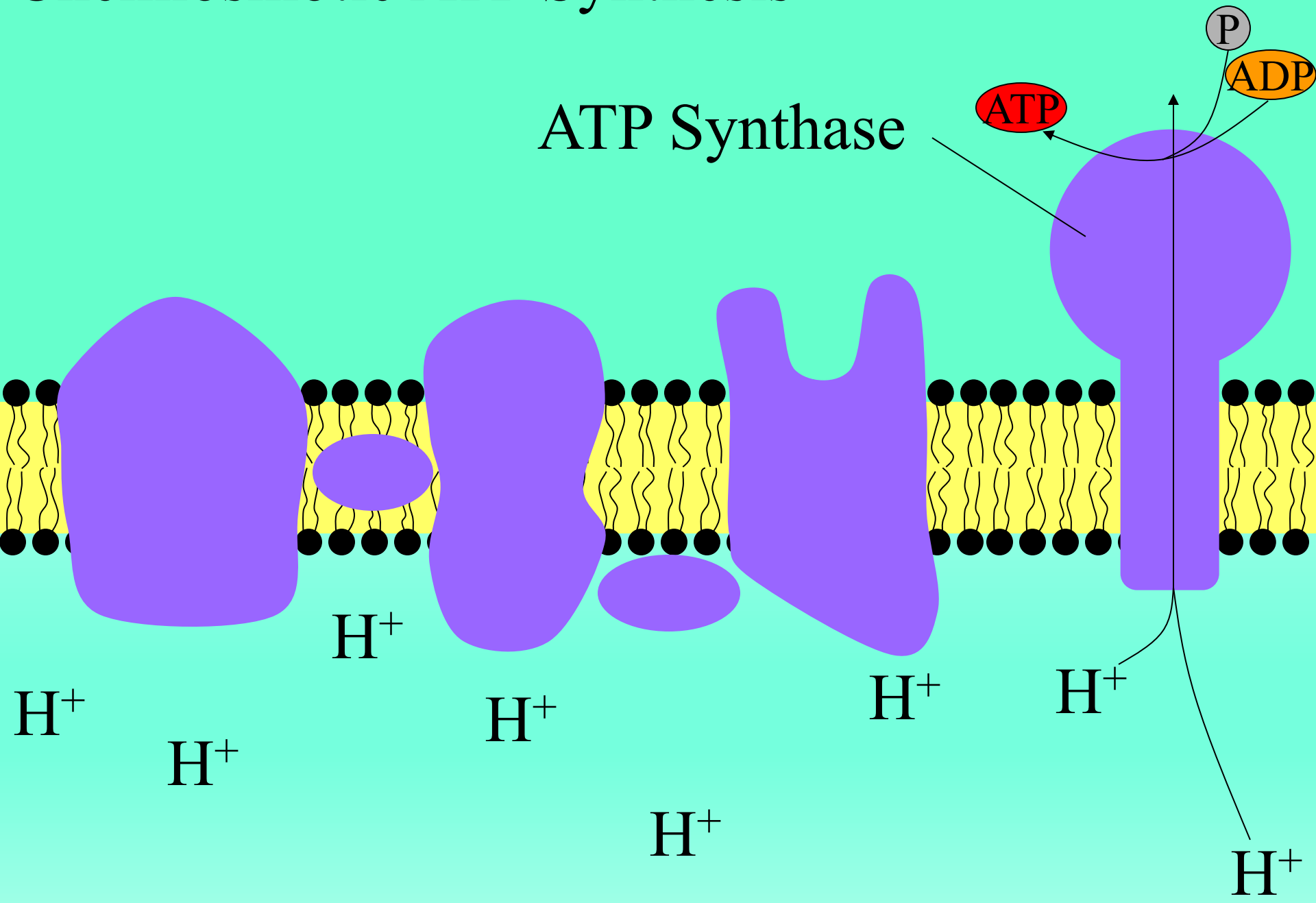
The Electron Transport Chain



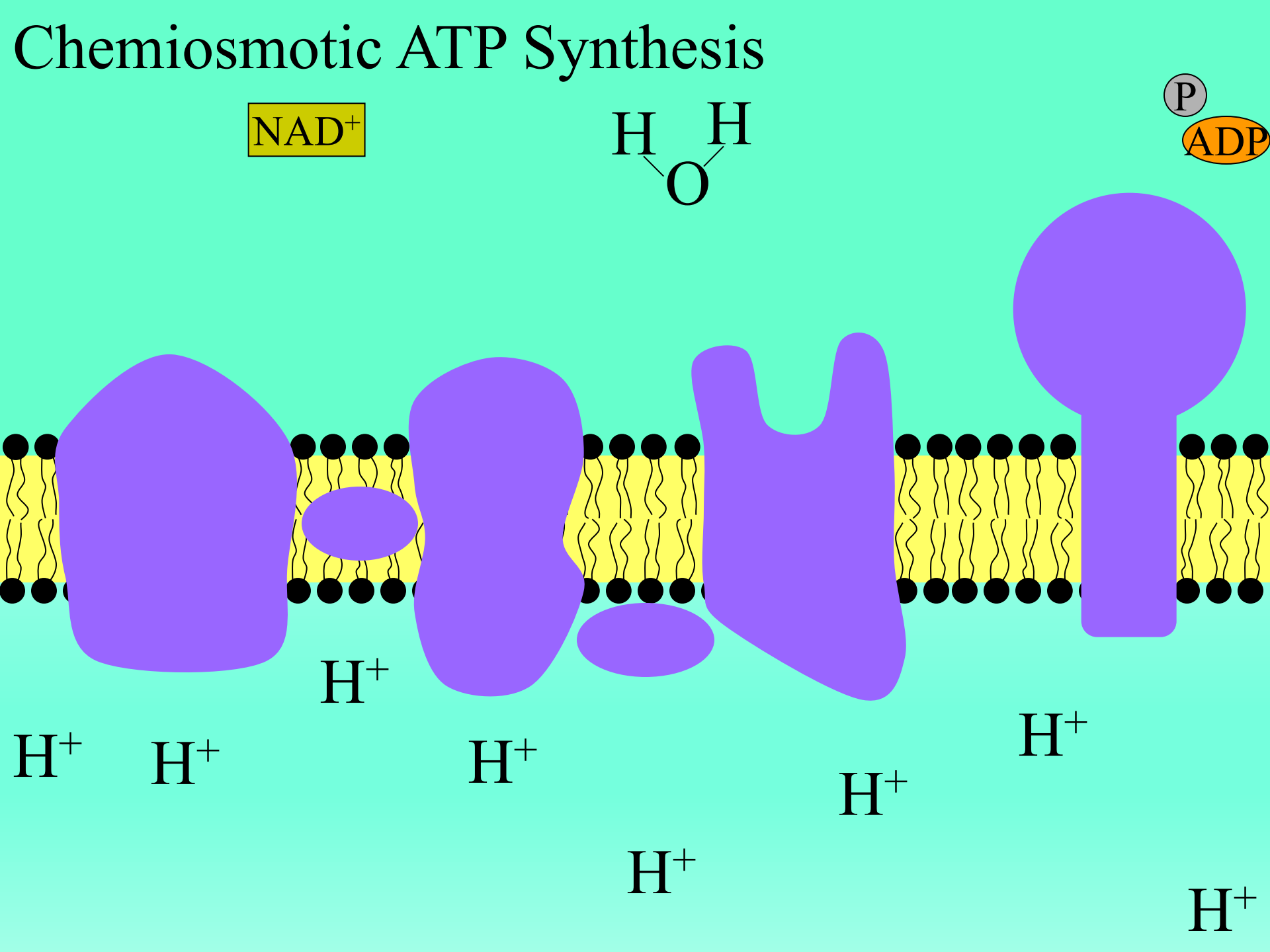
The Electron Transport Chain



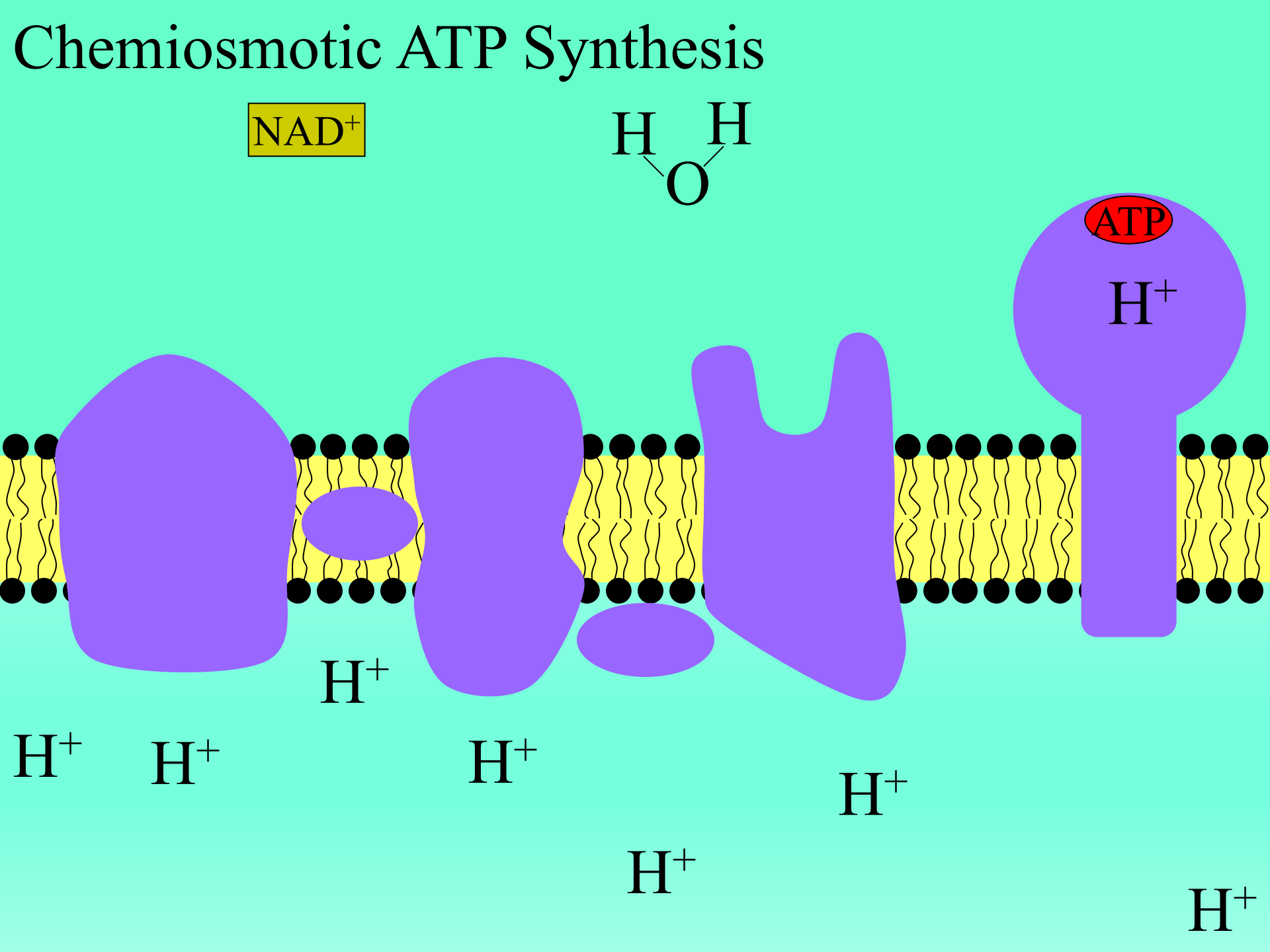
Chemiosmotic ATP Synthesis



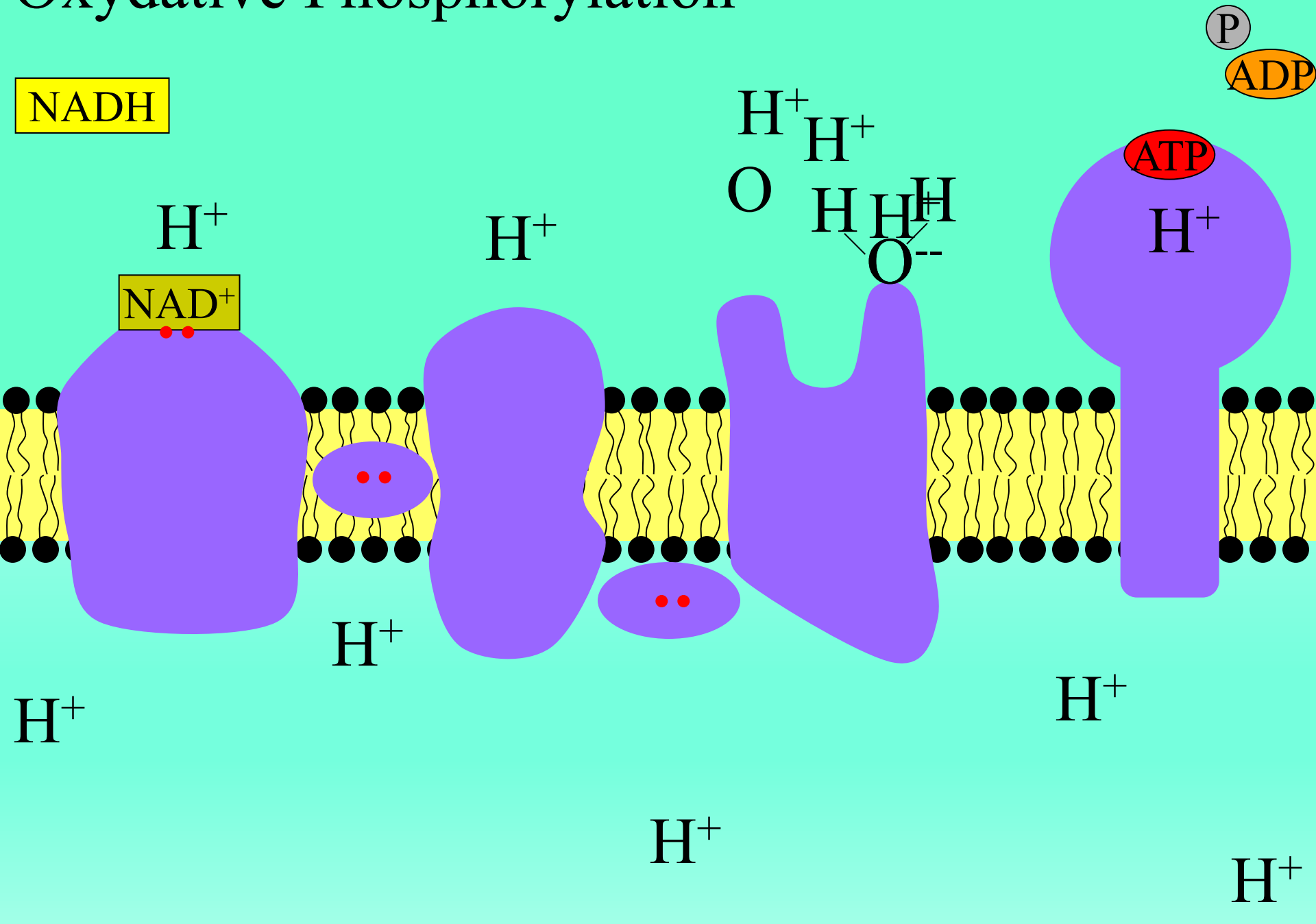
Chemiosmotic ATP Synthesis



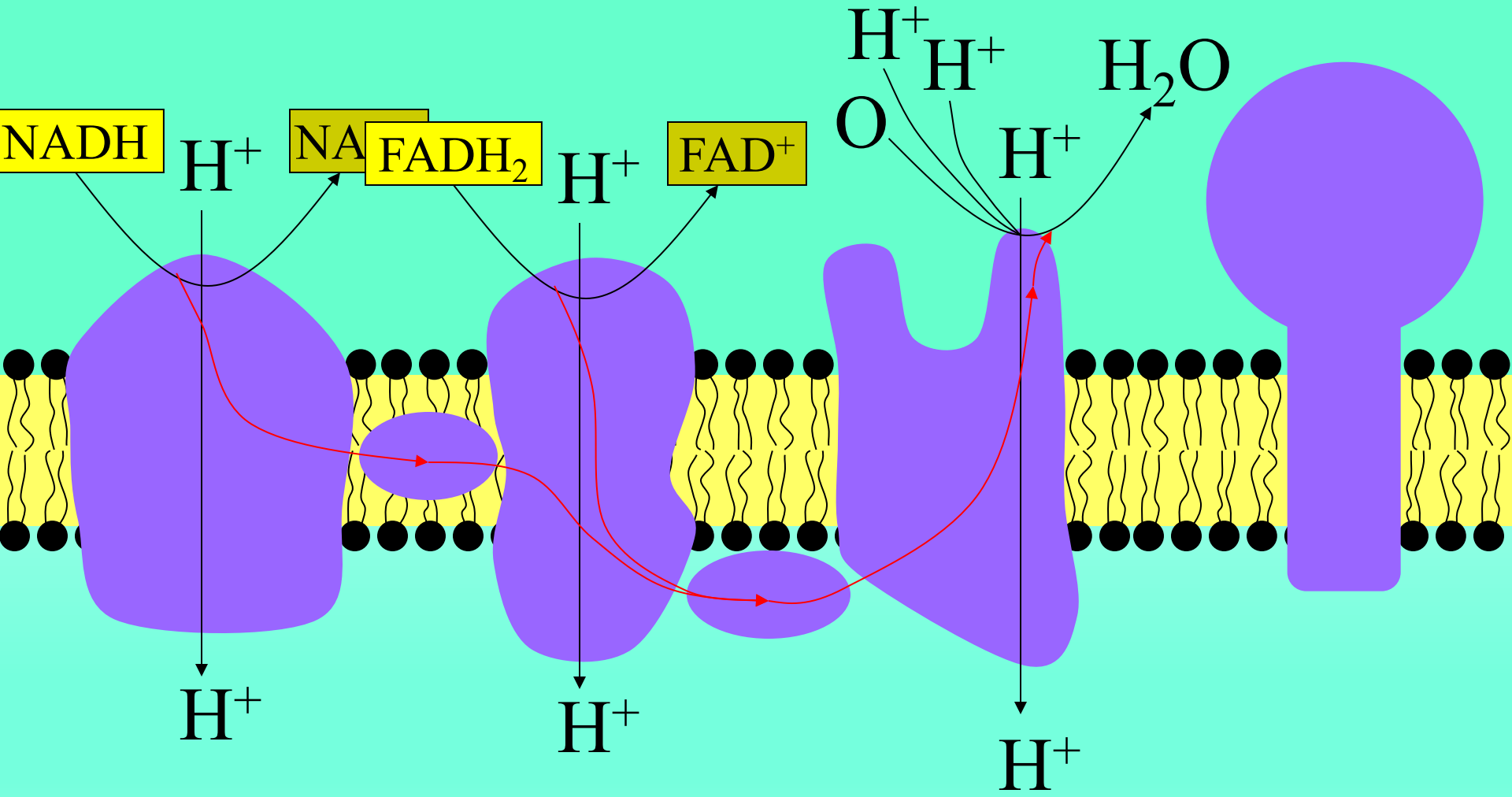
Chemiosmotic ATP Synthesis



Oxydative Phosphorylation



Oxydative Phosphorylation



Oxydative Phosphorylation

NADH ➡ 2.5 ATP $FADH_2$ ➡ 1.5 ATP

glycolysis: 2 ATP +

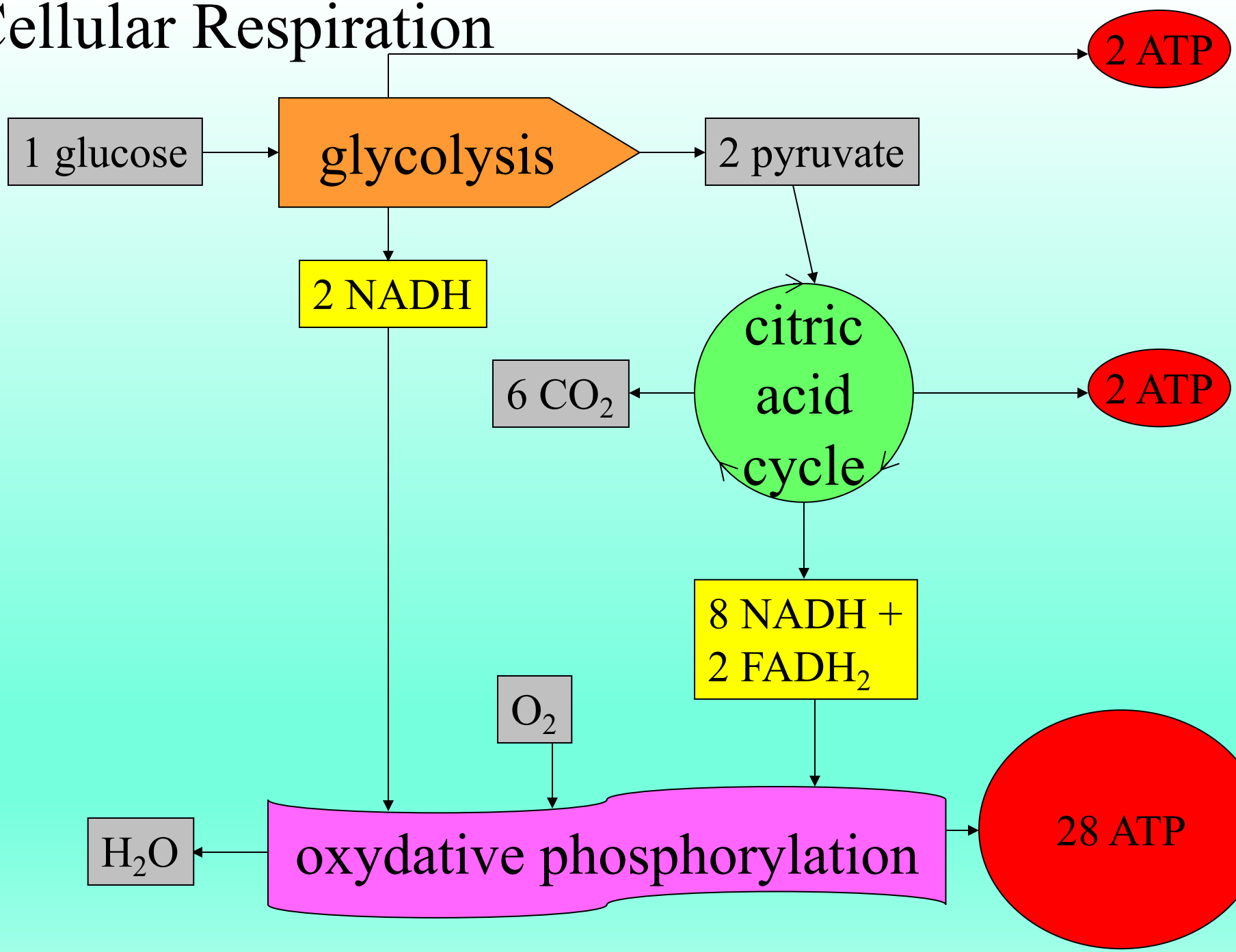
2 NADH ⟶ 5 ATP

the citric acid cycle: 2 ATP +

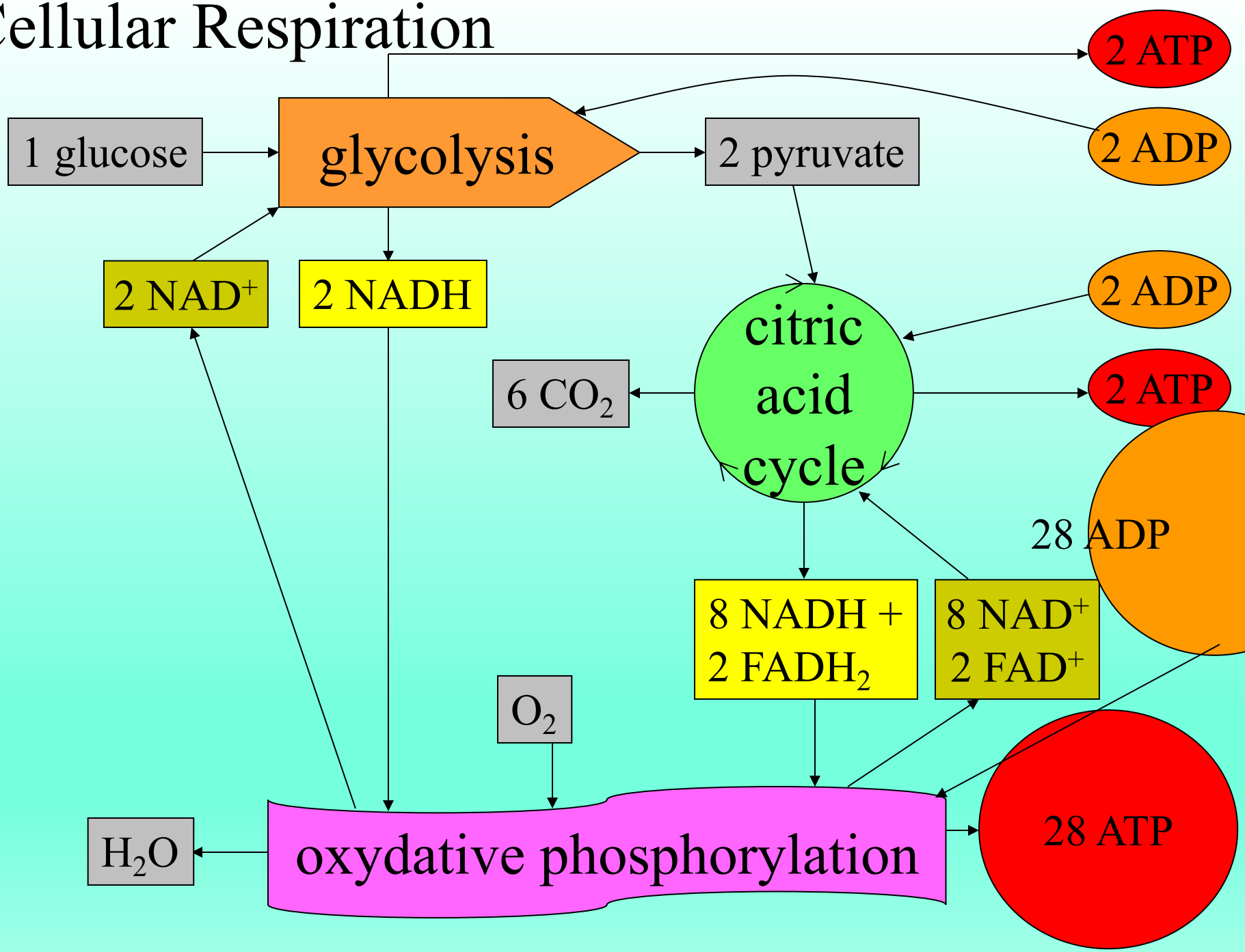
8 NADH ⟶ 20 ATP

2 $FADH_2$ ⟶ 3 ATP

Cellular Respiration

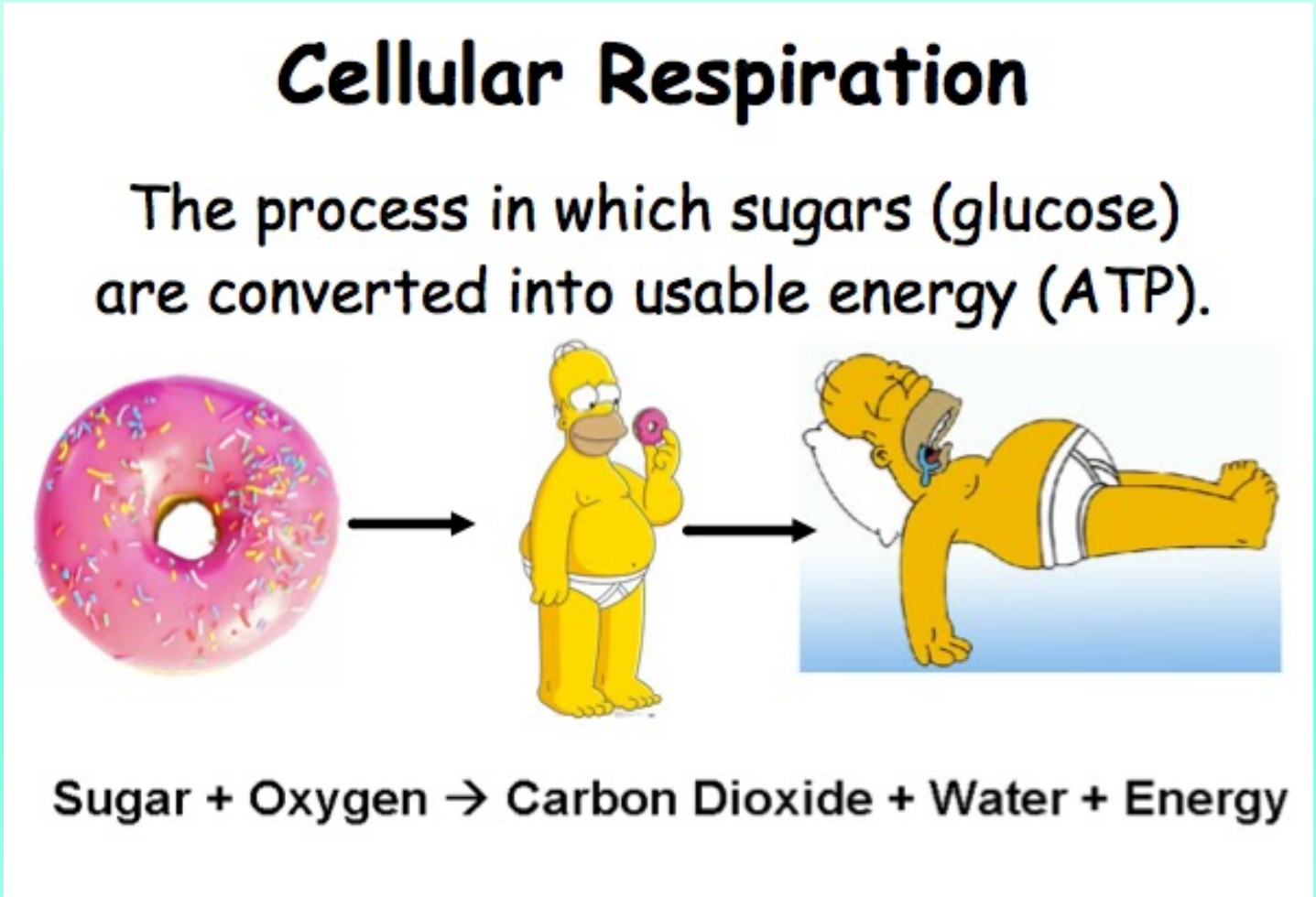


Cellular Respiration

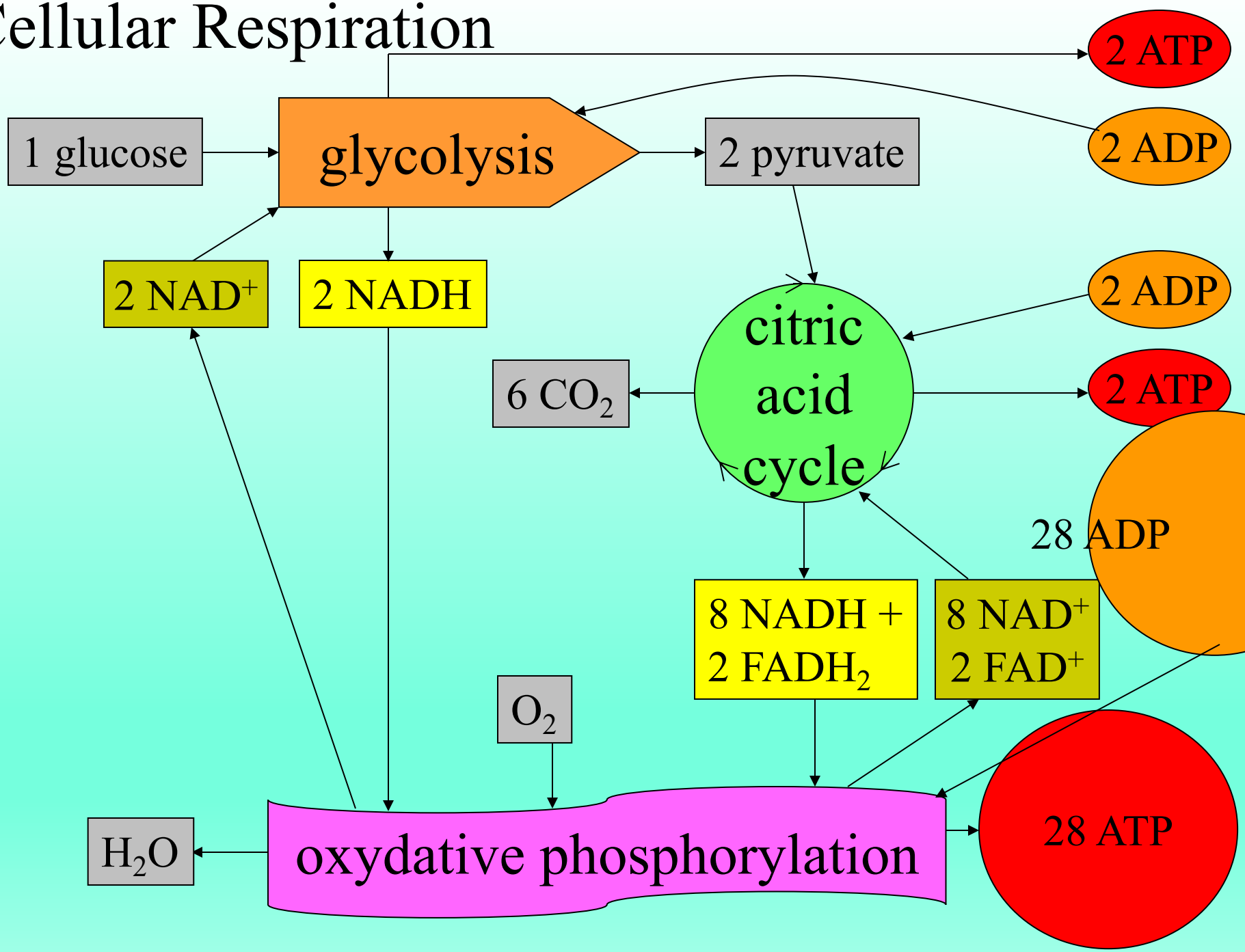


Cellular Respiration

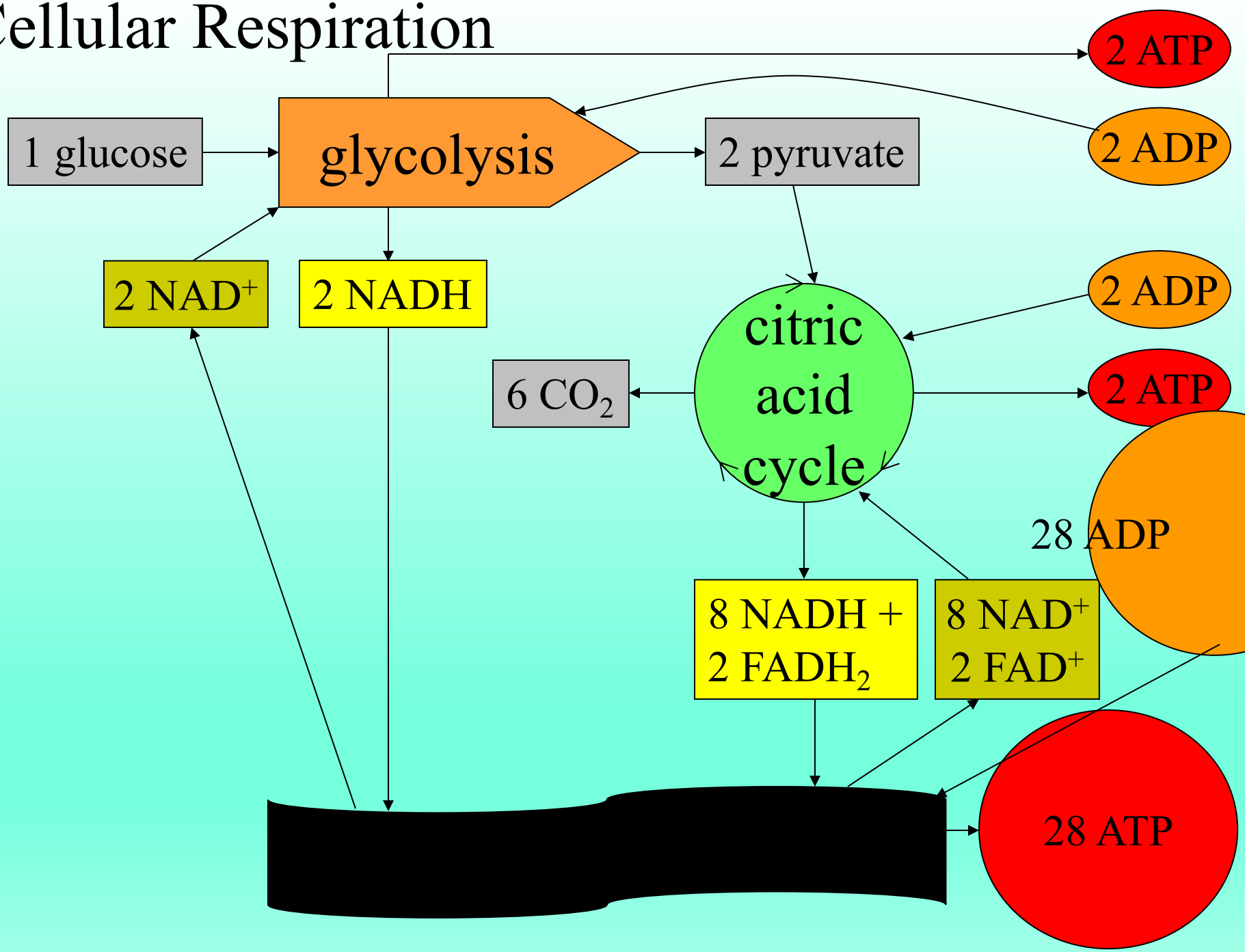
$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$ + energy (in ATP and heat)


Cellular Respiration
The process in which sugars (glucose) are converted into usable energy (ATP).
Sugar + Oxygen → Carbon Dioxide + Water + Energy

Cellular Respiration



Cellular Respiration



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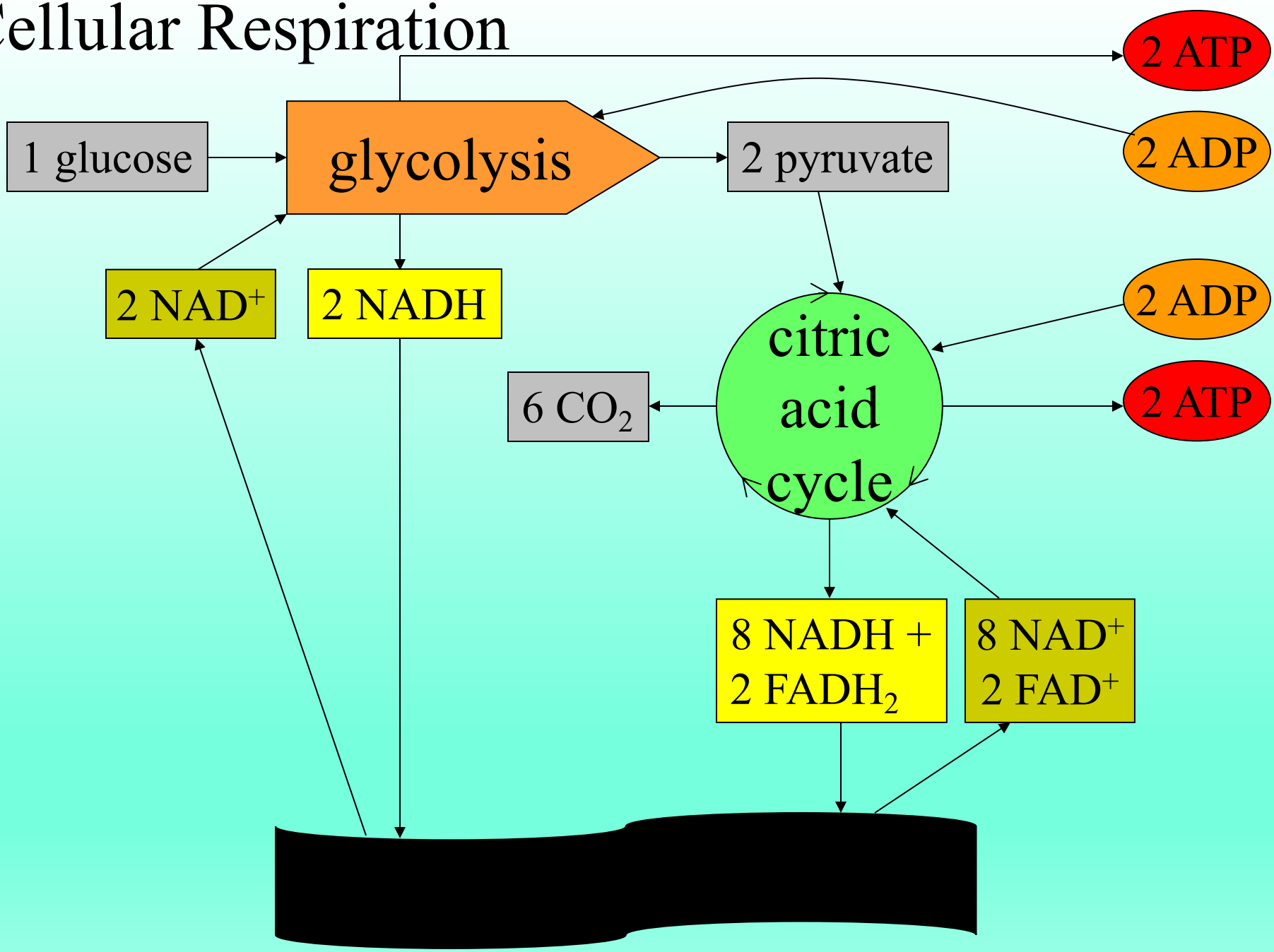

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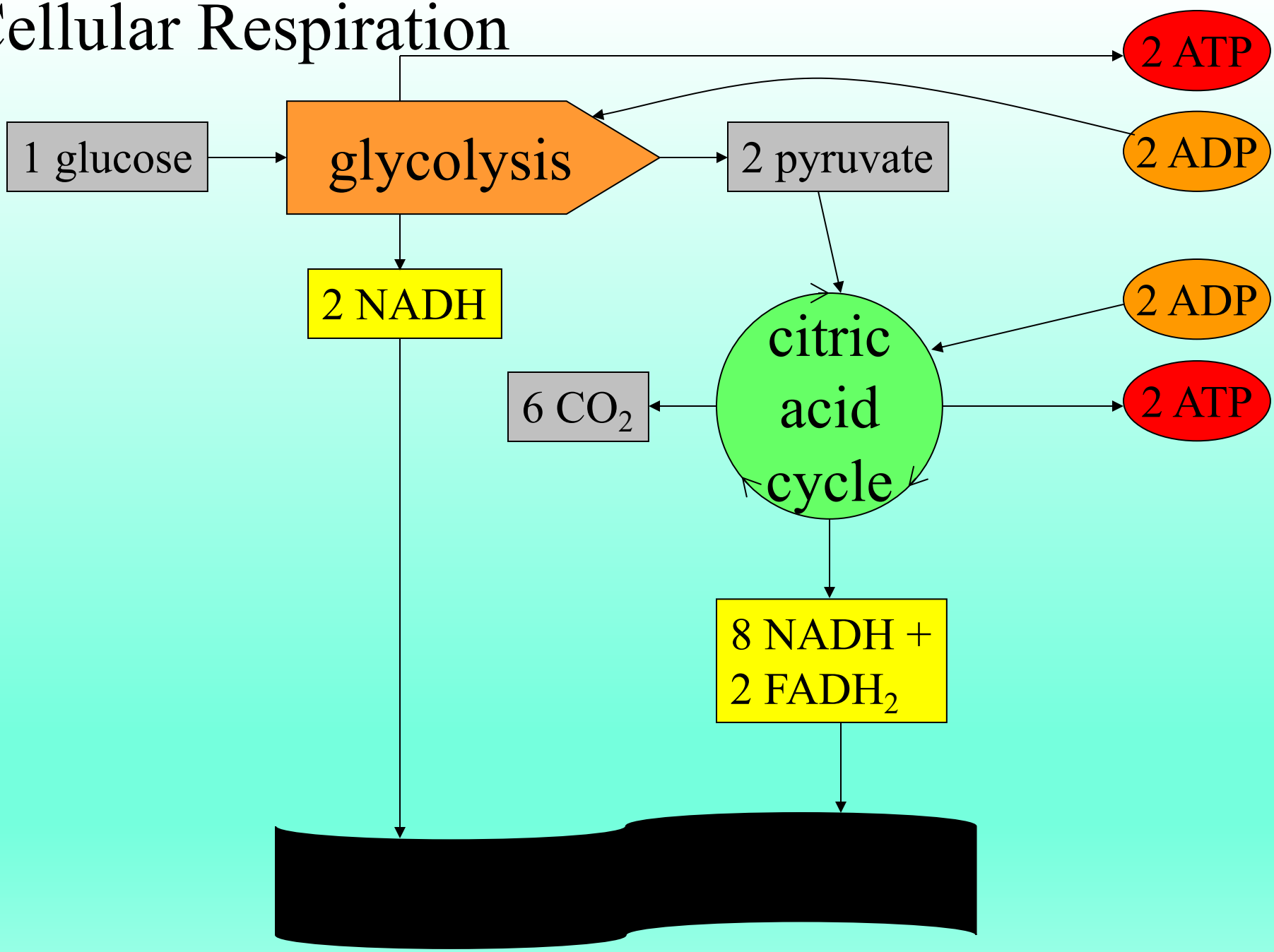
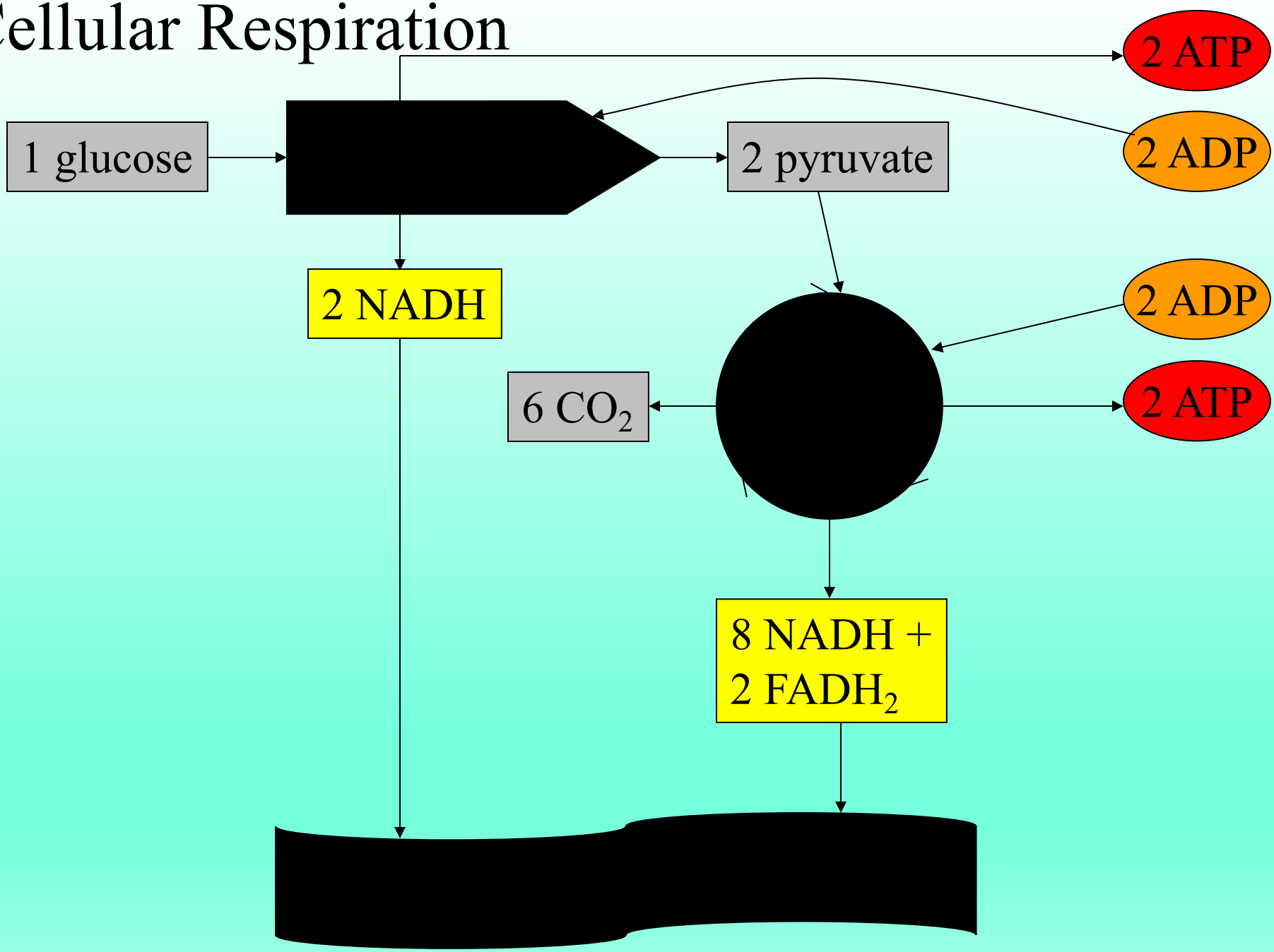
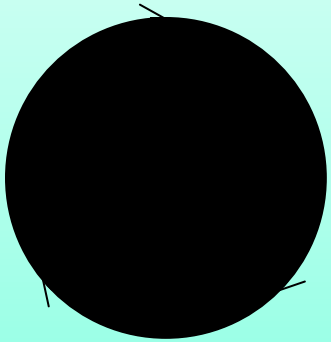


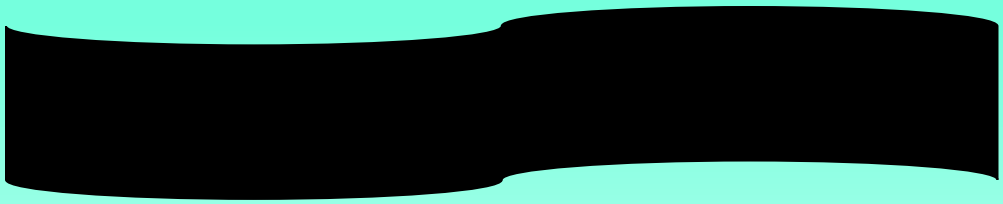
Cellular Respiration



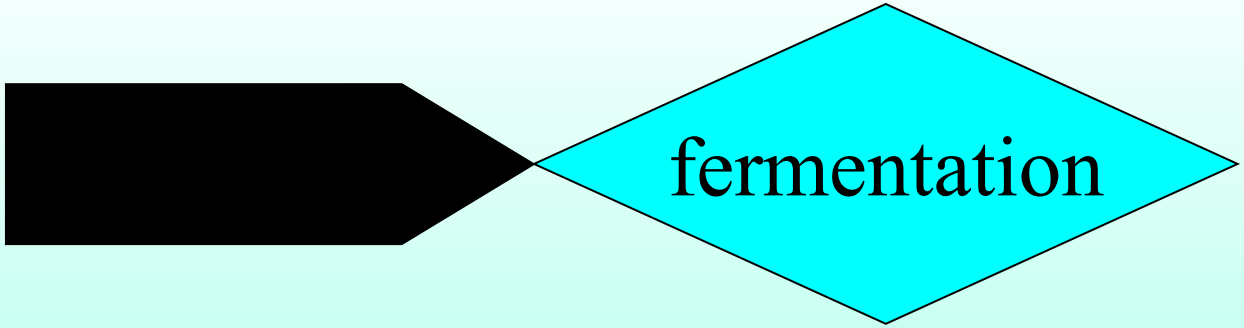
Cellular Respiration

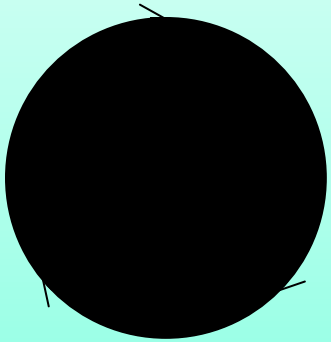
1 glucose

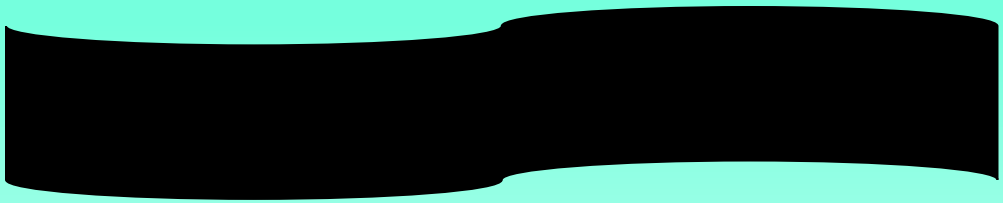




1 glucose



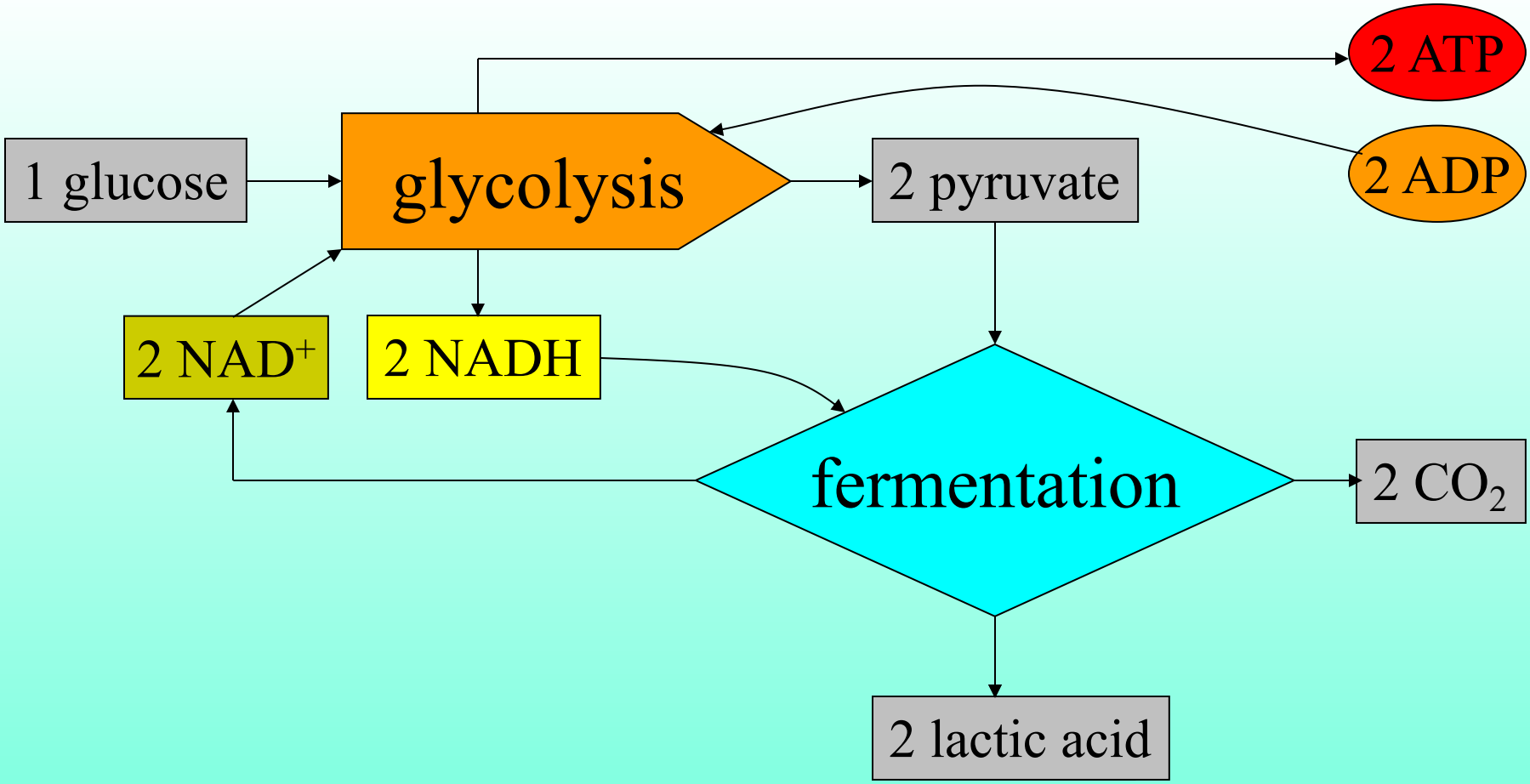




FERMENTATION

A metabolic pathway that changes pyruvate.

Much less efficient than cellular respiration, only used in the absence of oxygen.


2 ATP
1 glucose
glycolysis
2 pyruvate
2 ADP
2 NAD+
2 NADH
fermentation
2 CO2
2 lactic acid

Biochemical Pathways - Metabolic Pathways

http://www.expasy.ch/cgi-bin/show_thumbnails.pl